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14. ABSTRACT
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Emotional intelligence (EI) is the ability to accurately perceive, understand, and use emotional information toward adaptive functioning. We aimed to validate the basis of EI as a construct and whether it is indeed unique from traditional IQ. One analyses calls into question the divergent validity of self-report EI measures from existing personality and emotional well-being measures. We also investigated the evaluation of trustworthy faces, and found that individuals who were better at discriminating between overtly presented trustworthy and untrustworthy faces showed greater task-related activation of facial feature and affect processing systems during subliminal presentation of facial signals of trustworthiness. Further fMRI data showed that ability and trait measures of EI were associated with increased responsiveness of a brain region thought to be critical for social emotions during subliminal presentation of trustworthy faces. Additionally, we examined the association between gray matter volume (GMV) and the ability to detect and appreciate humor, and found several structures in the left hemisphere that correlated with humor appreciation scores. Furthermore, we looked at the relationship between amount of sleep and inhibitory abilities. These analyses have revealed that daytime sleepiness and typical amount of sleep relate to self-reported appetite, responsiveness to food stimuli, and GMV in some cortical regions.

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Emotional Intelligence (EI), functional Magnetic Resonance Imaging (fMRI)

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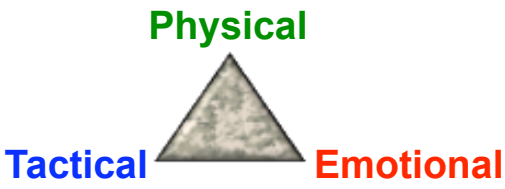
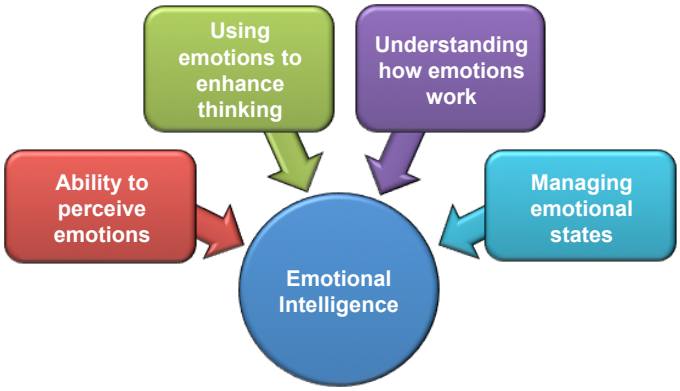
INTRODUCTION:

Soldiers need to be well equipped and effectively trained to function effectively in combat. Not only does this training need to include basic physical conditioning and tactical skills, but it must also prepare the warfighter to deal effectively with the emotional stresses associated with military operations. The U.S. Army continues to make important advances in the development of new equipment, approaches to physical training, and education in tactical capabilities. In contrast, comparatively little effort has been aimed at developing the emotional skills that Soldiers need to cope effectively with the stresses of combat or bounce back from the mental and emotional strains that are encountered during deployment. Just as a Soldier with inadequate training, poor physical conditioning, and insufficient body armor is at great risk of battlefield injury, so too a Soldier with poorly developed emotional capacities and fragile coping abilities is at increased risk for psychological wounds including depression, post-traumatic stress disorder, and even suicide. Renewed efforts to promote and develop emotional and mental resilience among warriors have led to the recent implementation of psychologically based initiatives such as the U.S. Army's Battlemind and Comprehensive Soldier Fitness programs. While these programs represent an important move to protect the mental health of Soldiers, they have been limited by the dearth of knowledge regarding the underlying neurobiology that contributes to the emotional capacities that allow a Soldier to cope effectively and remain resilient in the face of extreme and difficult challenges.



The ability to use emotions and emotional information to function adaptively across a variety of situations is known as Emotional Intelligence (EI) (1). There are a number of competing theories of EI, but one of the most widely accepted views suggests that EI comprises 4 major domains, including 1) the ability to perceive emotions in others, 2) the ability to use emotions to enhance thought processes and problem solving, 3) knowledge and understanding about how emotions work, and 4) the ability to manage and control emotional states to achieve long-term goal states. Just as standard cognitive intelligence provides the foundation for successful learning, problem solving, and adaptation to a variety of occupational, educational, and intellectual settings, it is likely that EI capacities provide the foundation for successful coping and resilience across a variety of emotionally challenging situations (2, 3), including those encountered during military operations. In order to effectively identify these capacities and promote their enhancement among Soldiers through targeted training programs, it will be necessary to understand the brain-behavior links that serve as the foundation of EI. At present, there



is almost no information regarding the underlying brain systems involved in EI (4). The goal of the present research project is to fill this information gap.

To provide a foundation for training and developing EI capacities among Soldiers, the present study involved using functional neuroimaging to map the neurocircuitry associated with normal variations in this capacity. During the funding period, 70 normal healthy participants ranging in age from 18 to 45 have completed a comprehensive neurocognitive assessment battery that includes two widely accepted measures of EI, assessment of standard cognitive intelligence (IQ), measures of coping, personality and resilience, as well as a host of emotional perception, decision-making, and problem solving tasks. These participants have also undergone several structural and functional magnetic resonance imaging scans at 3 Tesla while engaged in a variety of affective probe tasks designed to engage specific aspects of the neurocircuitry hypothesized to contribute to EI. The major goals of the study include: 1) identification of the neurocircuitry that is parametrically related to variability in EI scores, 2) evaluation of how EI brain systems differ from those of standard cognitive intelligence, 3) determination of whether the two commercially available tests of EI are measuring similar or different hypothetical constructs, and 4) determination of which test of EI is most predictive of brain activation within the hypothesized neurocircuitry and actual performance on emotional tasks. At present, we have run 70 participants through these procedures and report results on 65 of these individuals.

BODY:

Accomplishments According to Statement of Work (SOW)

The study is progressing as planned. Consistent with the Statement of Work for YEAR 3 the following tasks have been accomplished:

SOW 1. Data collection will be 100% completed by the start of the 3rd Quarter of Year 3.

Accomplishments:

- **Quarter #4**: All data collection has been completed.

SOW 2. The PI will analyze data and prepare manuscripts for publication during the second half of Year 3.

Accomplishments:

- **Year #3:** So far, four manuscripts have been accepted for publication in the peer reviewed literature and one is under review (see Reportable Outcomes).

SOW 3. The PI will prepare a final report describing the effectiveness of the EI training program for modifying EI abilities and the potential for future developments.

Accomplishments:

- **Quarter #4:** Due to the large amount of data collected and the important results that continue to emerge, we applied for and were granted a No Cost Extension (NCE) for 6 months. During this time, we continue to explore and further report on the data acquired from the study. A final close out report will be provided in March 2013.

Ongoing Research Findings

Beyond the basic accomplishments relating to the SOW, we have continued to analyze the acquired data and report on these analyses. Over the course of the study, these analyses have yielded a total of 44 scientific abstracts being written and presented at several scientific and professional conferences. These abstracts are attached as an Appendix. Below is a summary of the new findings that have emerged since the second annual report:

Convergent vs. Divergent Validity. We aimed to validate the basis of emotional intelligence (EI) as a construct and whether it is indeed unique from traditional IQ. We used ability and trait measures of EI, which themselves appear to evaluate different psychological constructs (Mayer-Salovey-Caruso Emotional Intelligence Test, MSCEIT; Bar-On Emotion Quotient Inventory, EQ-i; Self-Rated Emotional Intelligence Scale, SREIS). These were compared to examine their relationships with cognitive functioning (Wechsler Abbreviated Scale of Intelligence; WASI), Big Five personality traits (NEO-PI-R) and emotional well-being (Beck Depression Inventory, BDI; Positive and Negative Affect Schedule, PANAS). Results indicated that significant variability in the self-report EI measures was accounted for by personality and emotional well-being measures, whereas the MSCEIT was more strongly associated with IQ. Overall, nearly two-thirds (62%) of the variance in EQ-i scores was accounted for by Big Five personality traits, emotional well-being and full scale IQ; whereas only 14% of the variance in MSCEIT scores was accounted for by these same variables. We found that ability EI shares considerable variance with cognitive IQ (up to 28%), while trait EI appears to be primarily a measure of personality. The current study replicates and expands on previous research by examining the most commonly used EI measures and their relationships with cognitive functioning, Big Five personality traits and emotional well-being. Results indicated that 1) competing measures of EI exhibit surprisingly small correlations with one another, and 2) significant variability in the self-report (but not performance-based) EI measures was accounted for by personality and emotional well-being measures. In summary, the current findings raise questions regarding the divergent validity of self-report EI measures from existing personality and emotional well-being measures.

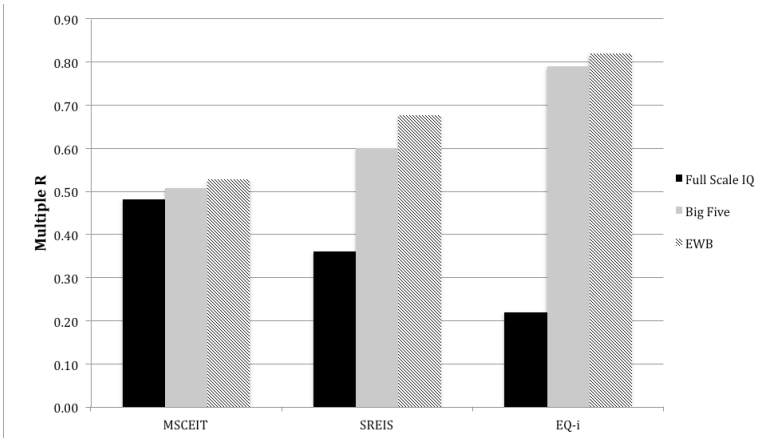


Figure 1. Multiple *R*s for Full Scale IQ, Big Five traits and emotional well-being (EWB) scales regressed on total EI scores for the MSCEIT, EQ-i, and SREIS. Three hierarchical multiple regressions were conducted (one for each EI measure). For each regression, independent variables were entered in three blocks (Full Scale IQ in Block 1, Big Five traits in Block 2, emotional well-being scales in Block 3).

Decision-Making. We were also interested in the relationship between EI and performance on the Iowa Gambling Task (IGT), a task that involves emotional decision-making in risky situations. We compared IGT performance with participants' scores on an ability measure of EI, a trait measure of EI, and an IQ measure. We found that participants who scored higher on the ability EI measure did better on the IGT than those who had lower scores, while there was no relationship between scores on the trait EI measure and IGT performance. However, the association between ability EI and IGT performance was no longer significant once we statistically controlled for IQ in the analysis. These findings suggest that ability EI may be a better predictor of performance in an emotional decision-making task, although the considerable shared variance between ability EI and IQ raise doubts as to the unique predictive validity of ability-based EI.

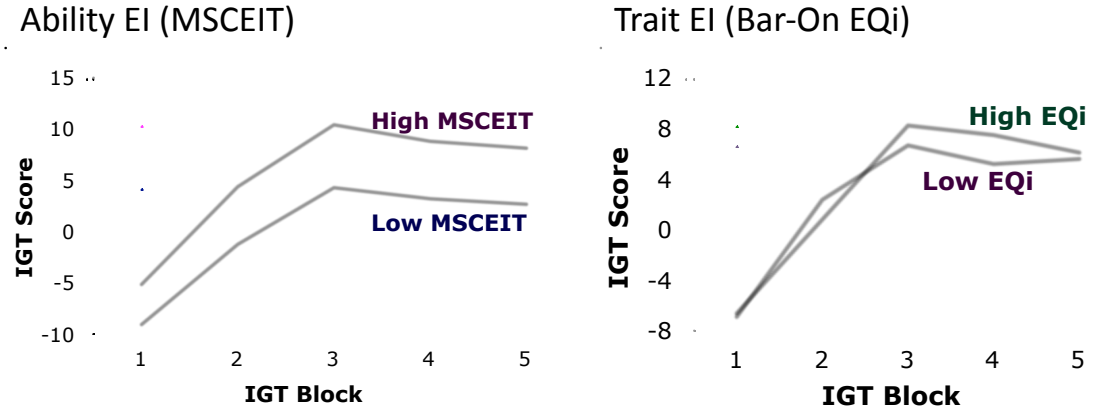
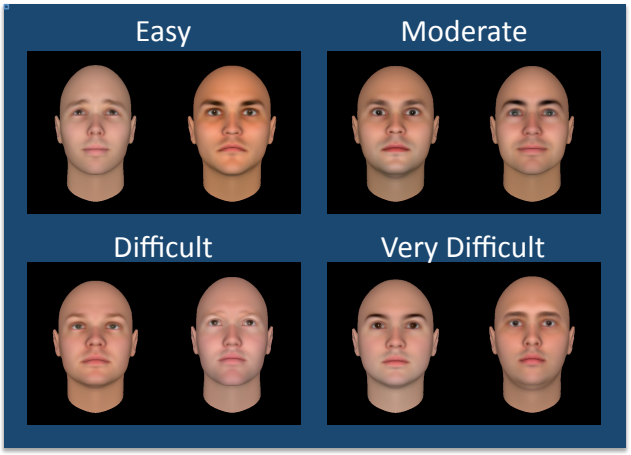
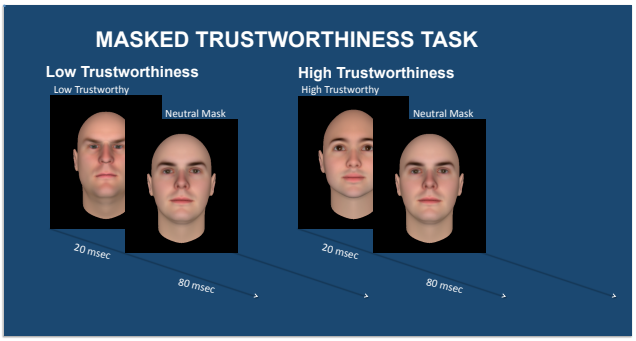


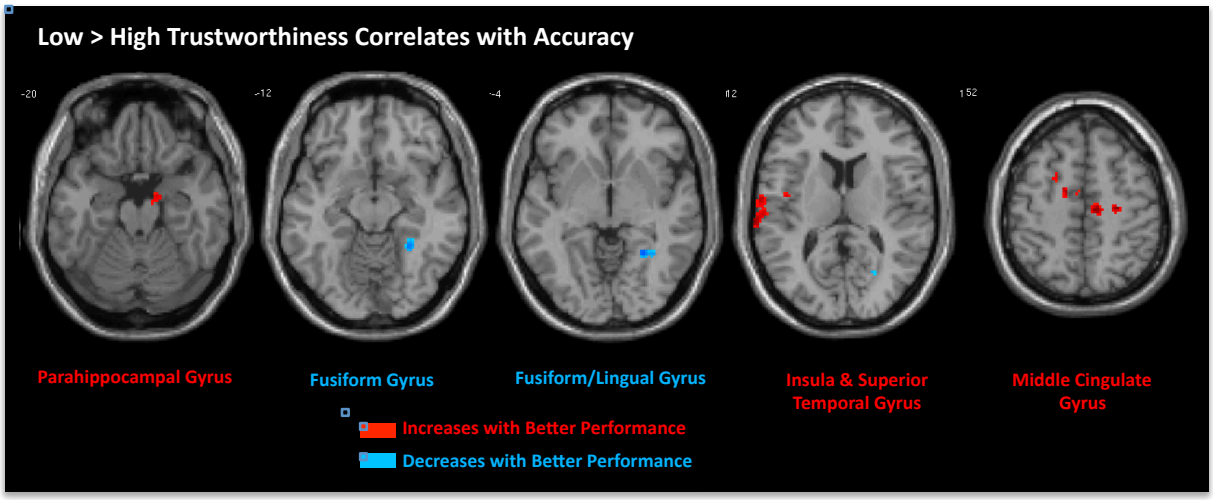
Figure 2. Higher ability EI on the MSCEIT was associated with better overall performance on the Iowa Gambling Task (IGT) than lower ability EI. In contrast, high and low EQi did not differ in performance on the IGT.

Evaluation of Overt Trustworthiness. The ability to identify trustworthy individuals is a critical aspect of human survival and is likely related to general EI capacities. Overt perception of untrustworthiness has been shown to activate the amygdala, but it is not clear how these patterns of activation relate to the actual ability to discriminate facial cues of trustworthiness. We examined data from thirty-six healthy adults (20 male) ranging from 19 to 45 years of age underwent fMRI while viewing masked presentations

of faces classified as either Trustworthy (T) or Untrustworthy. Conscious perception of trustworthiness cues was prevented via rapid presentation of the target face (20 msec), which was masked immediately by a neutral expression (N) mask (80 msec). Afterword, participants made overt trustworthiness judgments (OTJ) for 100 pairs of faces differing in qualities of trustworthiness. Contrast images comparing T and U fMRI conditions were regressed against OJT accuracy scores in the SPM8 brain imaging software package. During T>U contrasts, greater accuracy on the OTJ task correlated with increased activation within face processing regions of the fusiform and lingual gyri, and cerebellar vermis. During U>T contrasts, OTJ accuracy correlated with increased activation within affect processing regions such as the medial prefrontal cortex, insula, and hippocampus, and at a more liberal threshold, bilateral amygdala. Individuals who were better at discriminating between overtly presented trustworthy and untrustworthy faces showed greater task-related activation of facial feature and affect processing systems during subliminal presentations of facial signals of trustworthiness.



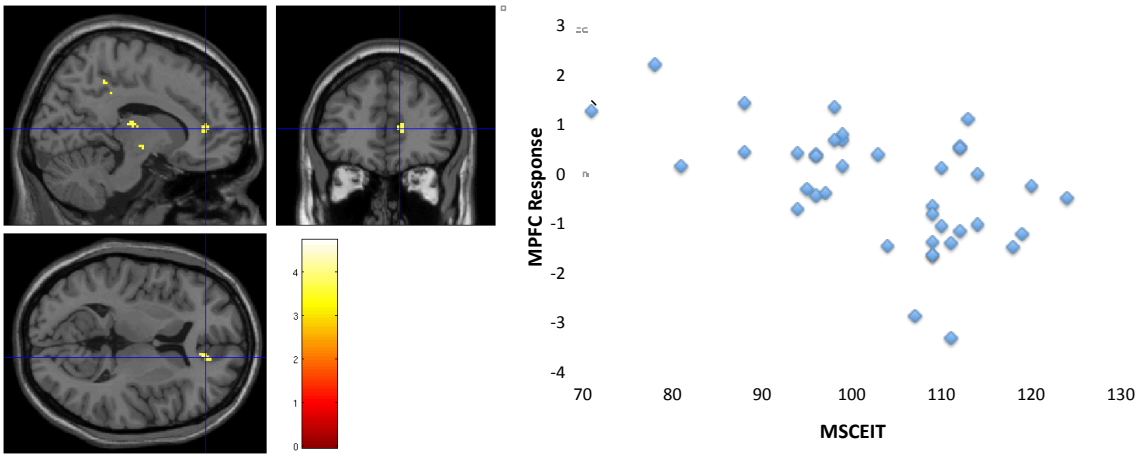




Evaluation of Subliminal Trustworthiness. We also sought to identify the brain regions involved in overtly evaluating facial expressions for trustworthiness and determine how this circuitry would be associated with emotional intelligence. Individuals who were better at discriminating between overtly presented trustworthy and

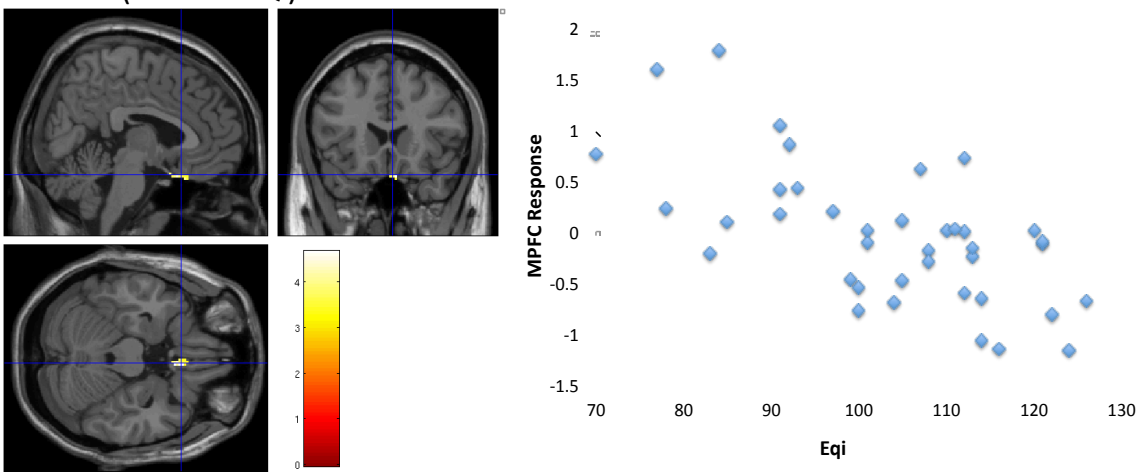
untrustworthy faces showed greater task-related activation of facial feature systems (fusiform and lingual gyri, cerebellar vermis) and affect processing systems (medial prefrontal cortex, insula, and hippocampus, and at a more liberal threshold, bilateral amygdala) during subliminal presentations of facial signals of trustworthiness. During such subliminal presentations, the ability and trait measures of EI were associated with increased responsiveness of insular cortex, a region of the somatic marker circuitry posited to be critical for social emotions and interoceptive processing (i.e., "gut feelings"). Higher EI may involve increased interoceptive sensitivity to stimuli with high social relevance.

Ability EI (MSCEIT)



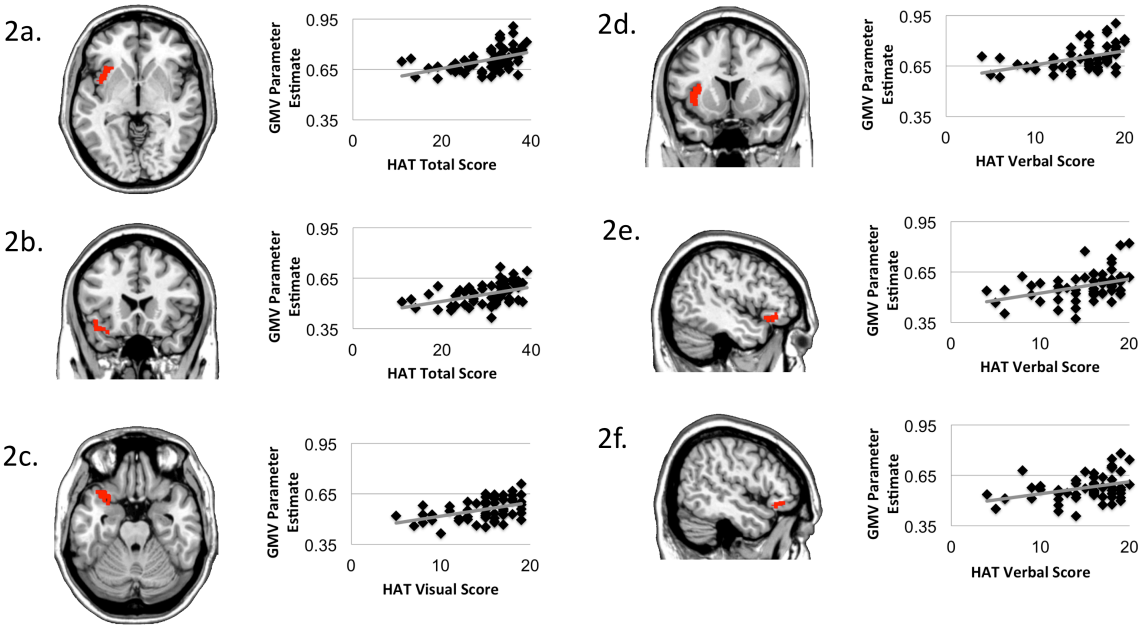
Rostral ACC: Higher MSCEIT was associated with lower activation of rostral anterior cingulate gyrus to faces that were more untrustworthy. **Amygdala:** No voxels were correlated with MSCEIT. **Insula:** No voxels were correlated with MSCEIT.

Trait EI (Bar-On EQi)



VMPFC: Higher EQi scores were associated with *lower* activation of the VMPFC when viewing Low vs. High trustworthy faces (i.e. higher EQ individuals were less responsive to untrustworthy faces). **Amygdala:** No voxels were correlated with Eqi. **Insula:** No voxels were correlated with EQi.

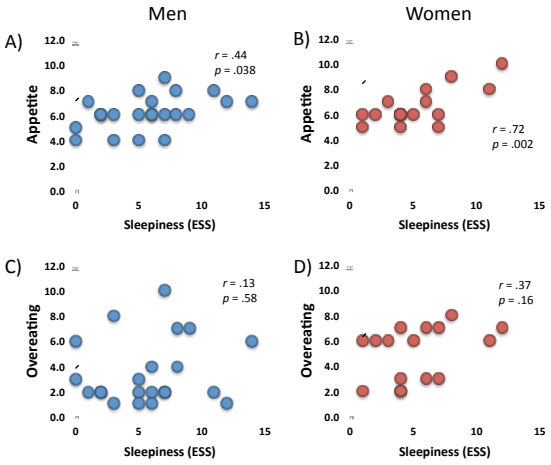
Humor Appreciation. An important aspect of emotional intelligence is the ability to appreciate humor, a complex cognitive process that remains poorly understood. Using voxel-based morphometry, we examined the association between gray matter volume and the ability to detect and appreciate humor. As evident in the figure below, we found that gray matter volume of the left inferior frontal gyrus, left temporal pole, and left insula correlated positively with the appreciation of visual and verbal humor on the HAT, while the gray matter volume of the right inferior frontal gyrus correlated only with verbal humor appreciation scores. These data support a neurobiological basis for humor appreciation, particularly involving left-hemispheric cortical systems, and further suggest that individual differences in humor appreciation may be related to differences in regional gray matter volume.



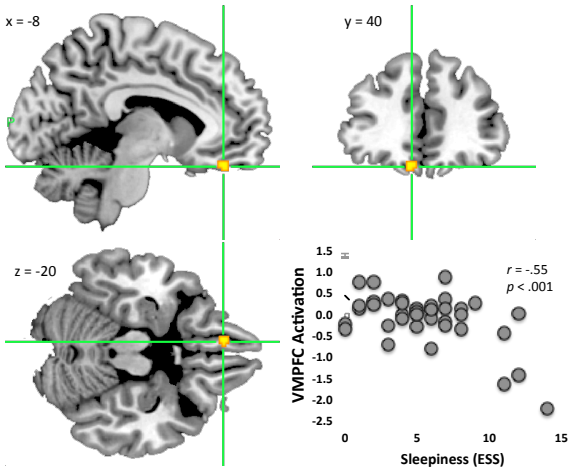
Hemispheric Functioning and Gender. Considerable evidence suggests that the right hemisphere may be more specialized for processing emotional facial expression information than the left, and this may differ as a function of gender. We examined the gender differences in the contribution of cognitive and emotional intelligence to the left visual field (LVF) bias for facial perception. Participants made choices among chimeric faces depicting a happy expression on one half and a neutral expression on the other.

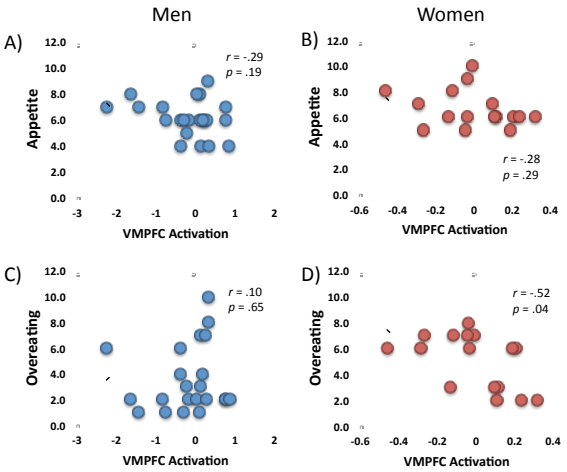
A bias score was calculated by determining the proportion of faces selected for which the expression was located in the LVF. For males, LVF bias was affected by cognitive and emotional intelligence, which appeared to have competing lateralized influences (i.e., cognitive intelligence = left hemisphere; emotional intelligence = right hemisphere. In contrast, the LVF bias of females appeared unrelated to cognitive or emotional intelligence. This suggests that emotional and cognitive intelligence may be organized within the brain differently among males and females.

Motivational Responsiveness and Sleep. An important component of Emotional Intelligence is the ability to regulate behavior and motivation. Therefore, we investigated various aspects of brain responses to food images, an important motivational stimulus. In addition, we also looked at the influence of sleep on these motivational behaviors. First, we found that overall, daytime sleepiness was associated with increased self-reported appetite. This relation was true for men but was even stronger among women.



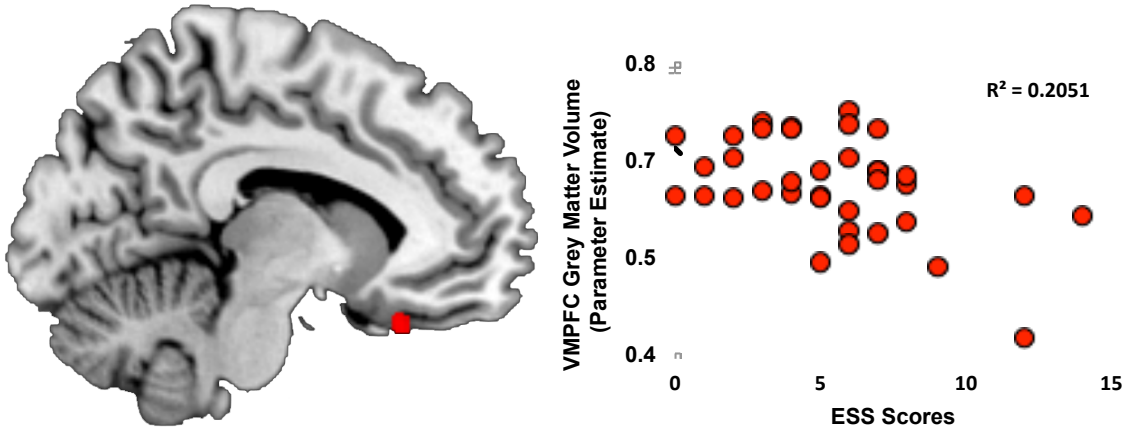
Second, we observed that that for participants viewing enticing high-calorie food images, greater daytime sleepiness was associated with decreased activation in the prefrontal cortex (see Figure at right), a region implicated in emotional and behavioral modulation. Interestingly, activation of this region was directly correlated with overeating in women but not men. Taken together, these findings highlight a functional neurocircuitry that may be relevant to overeating, as well as a relationship between daytime sleepiness and regulation of food intake. Normal fluctuations in sleepiness may be sufficient to affect brain regions important for regulating food intake. The observed sex differences in these results suggest that sex differences in the prevalence of eating disorders may be related to differential activation of this neurocircuitry.



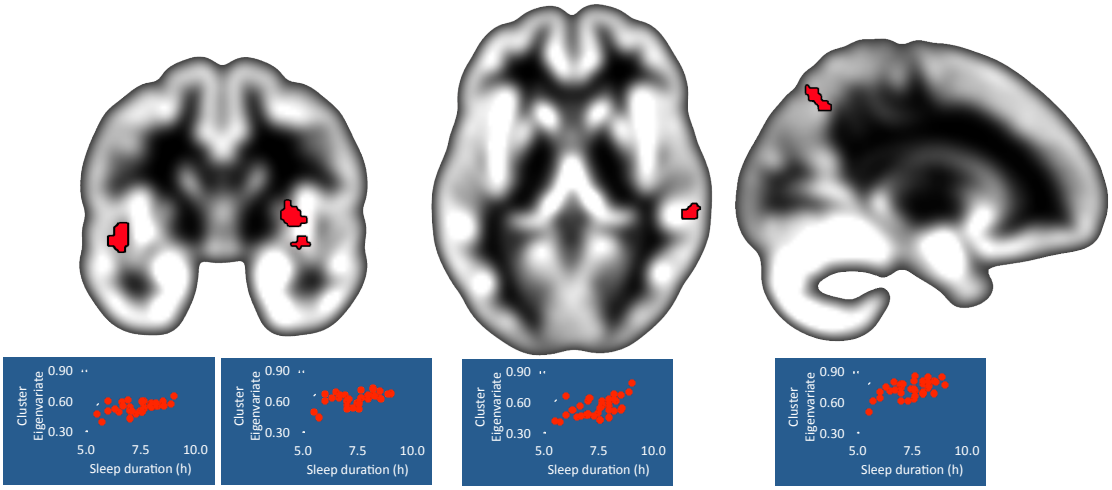


Sleep, Chronotype, Caffeine and Brain Structure. As a secondary aim of our study, we have also looked at gray matter volume and its relation to a number of variables related to sleep and caffeine use. We applied voxel-based morphometry to investigate gray matter correlates of typical daytime sleepiness that was measured with the Epworth Sleepiness Scale (ESS). Irrespective of age, gender, sleep duration and caffeine intake habits, greater sleepiness predicted small gray matter volume in a cluster in the left

ventromedial prefrontal cortex. Interestingly, this area corresponds to that of Thomas at al. (2000) showing the greatest reduction in glucose metabolism following sleep deprivation. This suggests that ventromedial prefrontal cortex is involved in sleep-wake regulation, but the direction of this association needs to be established in future research.



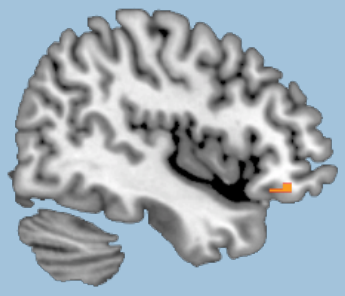
In addition, most people do not routinely obtain the sleep they need to maintain optimal daytime performance, but it is currently unknown whether average sleep duration is associated with brain morphology. We therefore conducted a voxel-based morphometric study of gray matter correlates of self-reported average sleep duration. Average nighttime sleep was positively associated with greater gray matter volume in bilateral insular cortices. It remains to be shown, however, whether these morphological differences predispose or yield differences in sleep habits.



Individuals show considerable variability in preferences for diurnal activity and sleep. These preferences comprise a continuum of "morningness-eveningness," with morning chronotypes showing greater preference for activity in the morning hours and an earlier bedtime, while evening chronotypes show the opposite pattern. Our lab has previously reported a relationship between evening chronotype and greater verbal intelligence. Despite the robustness of this phenomenon, little is known about the underlying neurobiological mechanisms that may contribute to these individual differences.

Therefore, we also examined whether structural differences in prefrontal gray matter volume correlate with individual differences in circadian preferences. We found that the right lateral orbitofrontal cortex showed greater gray matter volume with lower scores on the Morningness-Eveningness scale (indicating greater "eveningness" chronotype. These findings suggest that some aspects of individual differences in the ability to function effectively at particular times of day may be due to variations in prefrontal cortex gray matter volume.

Orbitofrontal Cortex Region which correlated with MEQ overlaid on a single subject T1 with corresponding scatterplot



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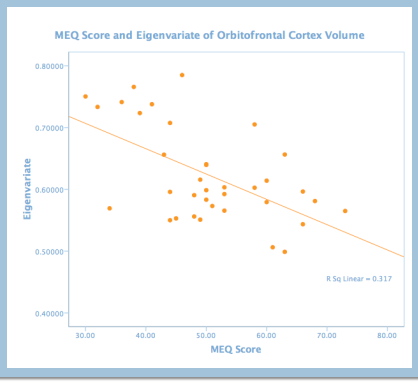
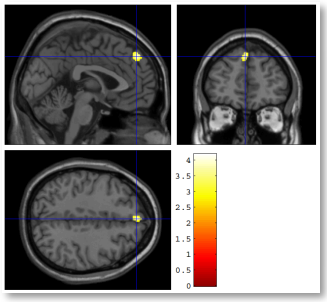
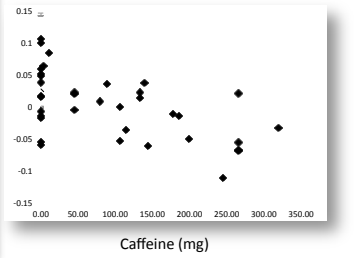
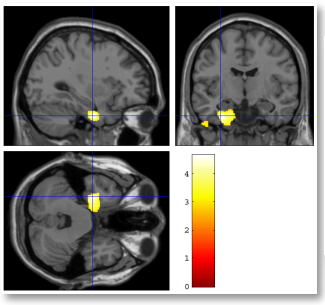
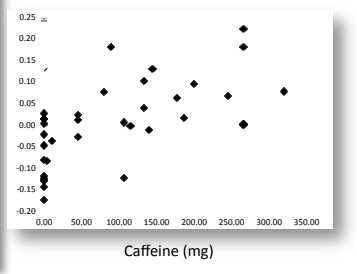


We also examined habitual caffeine intake and its relation to brain volume. Results suggested that greater caffeine intake was associated with reduced bray matter volume within the superior medial prefrontal cortex and increased volume within the left medial temporal lobe, including parahippocampal gyrus, hippocampus, amygdala, and fusiform gyrus. These findings suggest that habitual caffeine use may be associated with structural remodeling of some regions of the brain important for behavioral control and memory processing.



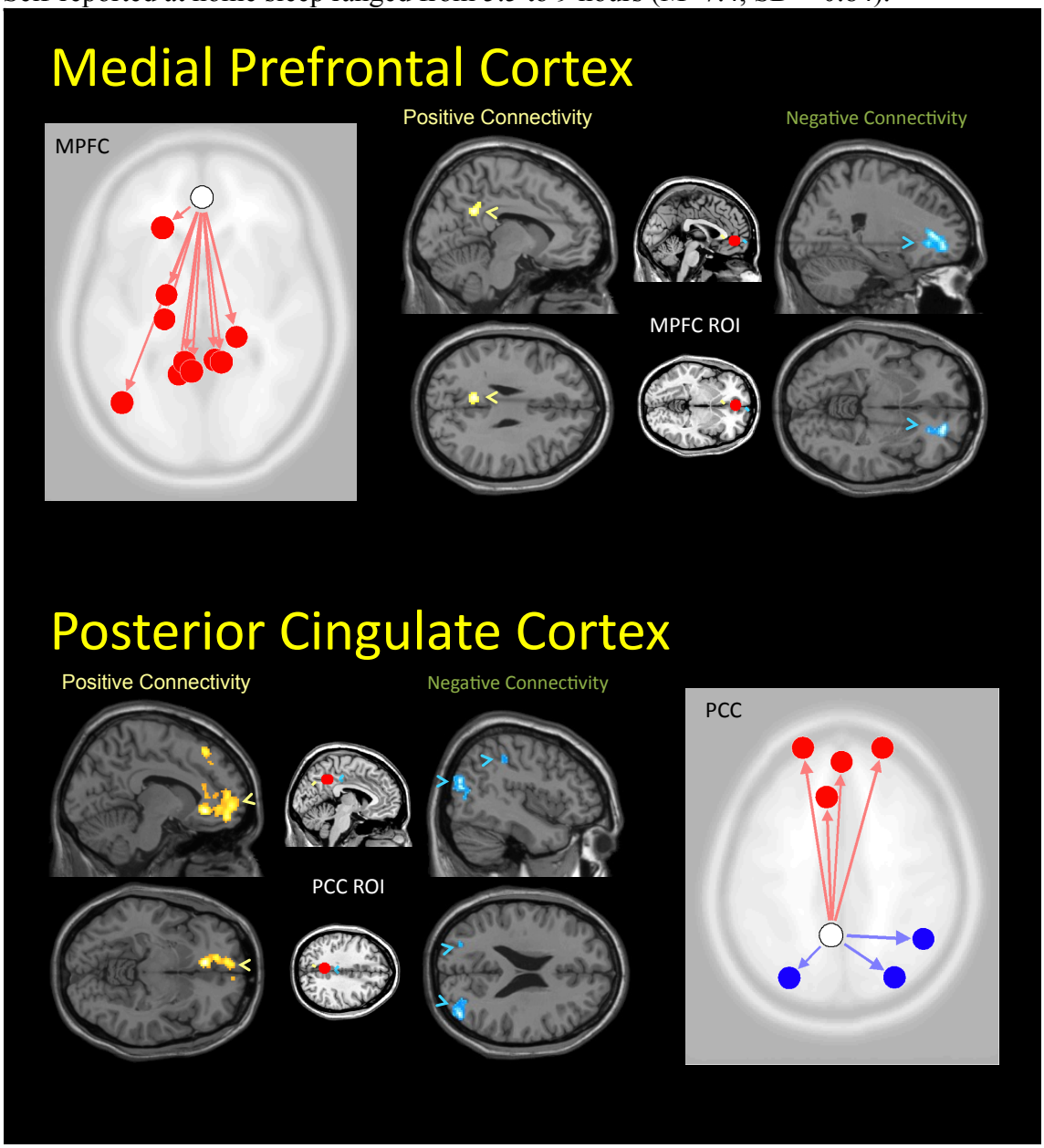






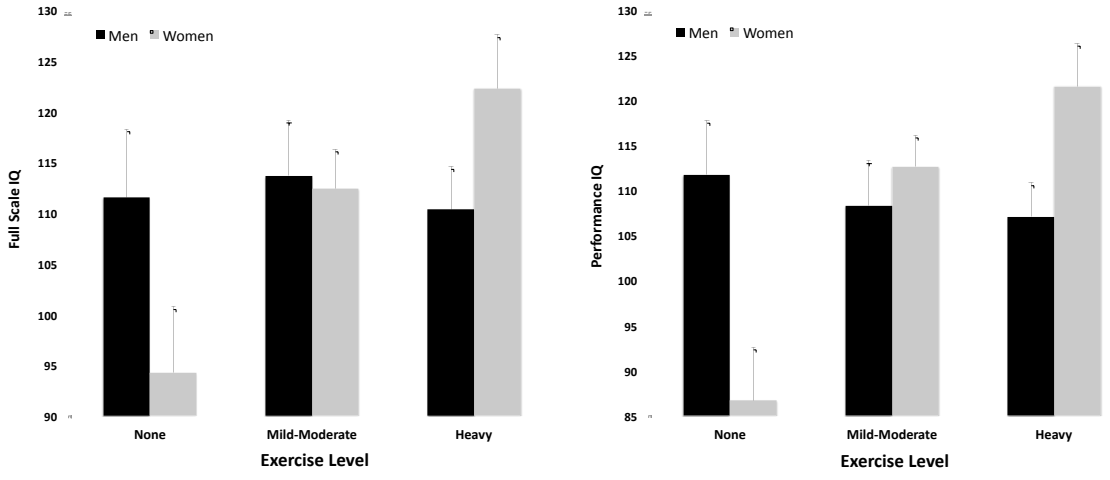
Lastly, we also examined the functional connectivity within the brain and its relation to the amount of sleep obtained the night before the MRI scan. Sleep deprivation is associated with reduced cerebral metabolic activity, particularly within medial regions of the brain commonly associated with the default mode network. Recent evidence suggests that sleep deprivation also reduces the functional connectivity between the medial prefrontal cortex and the amygdala during emotional processing, possibly explaining

some of the mood and emotional changes often associated with sleep loss. Therefore, we examined the correlation between cerebral functional connectivity and the amount of sleep obtained the night preceding the neuroimaging scan among healthy volunteers who slept at home according to their own schedules. For this analysis, thirty-nine healthy individuals (ages 18-45, *M* = 30.4, *SD* = 8.7; 21 female) completed a questionnaire asking about their recent sleep habits. Participants underwent resting state functional magnetic resonance imaging (fMRI) for 6 minutes at 3T. Data were preprocessed in SPM8, including slice-time correction, segmentation, realignment, normalization, and spatial smoothing (6mm FWHM). The Functional Connectivity Toolbox (CONN) was used to regress out tissue- and movement-related nuisance covariates and to calculate seed-to-voxel and region-of-interest (ROI) to ROI random effects connectivity analyses. Self-reported at home sleep ranged from 5.5 to 9 hours (M=7.4, SD = 0.84).



More sleep was associated with significantly enhanced functional connectivity between the medial prefrontal cortex and dorsal posterior cingulate cortex, retrospenial cingulate, amygdalo-hippocampal region, and dorsal prefrontal cortex. Sleep was associated with greater positive connectivity between the posterior cingulate region and anterior prefrontal cortex, anterior cingulate, and medial prefrontal region, and greater anticorrelation with associative visual cortex. These findings suggest that even normal daily fluctuations in overnight sleep can have dramatic effects on functional connectivity within regions of the brain critical for emotional decision making.

Physical Exercise and Intelligence. Previous research suggests that physical exercise may have beneficial effects on cognitive performance in children and the elderly, but little research has yet examined these associations in healthy adults. Given that the goals of the present study involve examining EI and standard cognitive intelligence, we have conducted initial analyses to examine the relationship between physical activity levels and these capacities. It was hypothesized that self-reported frequency and duration of physical exercise would correlate positively with measured intelligence on the Wechsler Abbreviated Scale of Intelligence in healthy young to middle aged adults (25 men; 28 women). Although there was a modest positive association between physical exercise and intelligence for the group as a whole, when examined separately by sex, greater physical activity was associated with higher intelligence scores for women, whereas exercise level was essentially unrelated to intelligence among men (see figures below). These associations remained consistent even after controlling for demographic and socioeconomic factors. Although the causal direction of the relationship cannot be determined from these data, they strongly suggest that physical activity and cognitive ability are closely linked. The association between exercise and intelligence appears to be moderated by sex in healthy adults, possibly through its effects on glucoregulation, insulin sensitivity, or other factors that differ between men and women. We will examine the same relationships with EI in coming analyses.



KEY RESEARCH ACCOMPLISHMENTS:

- 70 participants have been enrolled, and the study is closed to new enrolment.
- 65 participants have completed scanning/study procedures, providing usable data.
- Data analysis is ongoing.
- 24 posters based on preliminary findings have been presented at professional conferences this year, and 44 presented overall during the course of the study.

REPORTABLE OUTCOMES:

- 5 posters were presented McLean Hospital Research Day, January 11, 2012 in Belmont, MA.
- 9 posters were presented at the 40th Annual Meeting of the International Neuropsychological Society in Montreal, QC, February 15-18, 2012.
- 1 poster was presented at the 67th Annual Meeting of the Society of Biological Psychiatry in Philadelphia, PA, May 3-5, 2012.
- 9 posters were presented at the 25th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.
- 6 manuscripts (attached and listed below) were accepted and/or published in scientific journals, and 1 manuscript is under review:

1. **Killgore, WD**, Weber, M, Schwab, ZJ, DelDonno, SR, Kipman, M, Weiner, MR, & Rauch, SL. Grey matter correlates of trait and ability models of emotional intelligence. Neuroreport 23, 551-555, 2012.

2. **Killgore, WD**, Schwab, ZJ, Kipman, M, DelDonno, SR, Weber, M. Voxel-based morphometric grey matter correlates of daytime sleepiness. Neurosci Lett, 518(1), 10-13, 2012.

3. **Killgore, WD**, Schwab, ZJ, & Weiner, MR. Self-reported nocturnal sleep duration is associated with next-day resting state functional connectivity. Neuroreport (in press).

4. **Killgore, WD**, & Schwab ZJ. Sex differences in the association between physical exercise and cognitive ability. Perceptual and Motor Skills (in press).

5. Kipman, M, Weber, M, Schwab, ZJ, DelDonno, SR, & **Killgore, WD**. A funny thing happened on the way to the scanner: Humor detection correlates with gray matter volume. Neuroreport (in press).

6. Killgore, WD, Schwab, ZJ, Weber, M, Kipman, M, DelDonno, SR, Weiner, MR, & Rauch, SL. Daytime sleepiness affects prefrontal regulation of food intake. (under review, NeuroImage).

CONCLUSION:

The study is progressing as planned and is consistent with the requirements of the SOW. We have completed data collection on 70 participants, yielding complete and usable data sets from 65 participants. The study is closed to further enrollment but remains open for data analysis only. Data quality checks and preprocessing have been completed and data analysis is currently underway.

Since the start of funding for this project 3 years ago, we have published/presented 44 abstracts, posters, and oral presentations at various scientific conferences and have already successfully published 5 manuscripts in peer-reviewed journals, with numerous others in submission and in preparation. Several of these initial findings have already received wide-spread attention in the scientific press and popular media, including write-ups in the Los Angeles Times (http://articles.latimes.com/2011/jun/14/news/la-heb-sleep-carbs-20110614), Chicago Tribune (http://articles.chicagotribune.com/2012-04-25/health/sc-health-0425-bit-of-fit-20120425_1_junk-food-unhealthy-food-high-calorie-foods), and stories on several television news programs. Our recent manuscript on functional connectivity has remained the most read article on the NeuroReport website (http://journals.lww.com/neuroreport/pages/default.aspx) since its publication on September 12, 2012. This same article was also selected to be the cover image and cover story to the same issue of the journal. Our recent paper on sex differences in the relationship between exercise and intelligence was also selected for press release as well (http://www.amsci.com/exercise-tied-to-higher-iq-in-women/). At present, we are still in the preliminary stages of analyzing and writing up the emerging findings from this extraordinarily rich data set. To permit continued analysis and publication of these data, we have requested and received a No-Cost Extension for an additional 6-months. During this time, we plan to continue in-depth analysis of the data and will initiate intensive preparation and submission of manuscripts based on emergent findings. We have also attempted to secure additional funding to build upon these findings by conducting an intervention study to see whether EI and emotional resilience capacities are modifiable through a training program and targeted use of transcranial magnetic stimulation (TMS), but have thus far been unsuccessful in obtaining funding for follow-on work.

REFERENCES:

1. Mayer JD, Salovey P, Caruso DR. Emotional intelligence as zeitgeist, as personality, and as mental ability. Bar-On R, Parker JD, editors. San Francisco: Jossey-Bass; 2000.
2. Mayer JD, Caruso DR, Salovey P. Emotional intelligence meets traditional standards for an intelligence. Intelligence. 1999;27:267-98.
3. Mayer JD, Salovey P, Caruso DR, Sitarenios G. Emotional intelligence as a standard intelligence. Emotion. 2001;1(3):232-42.
4. Bar-On R, Tranel D, Denburg NL, Bechara A. Exploring the neurological substrate of emotional and social intelligence. Brain. 2003;126(Pt 8):1790-800.

APPENDICES:

Page

Appendix: List of Assessments

1. Pre-Scan Information Questionnaire (PSIQ)
2. Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT V2.0)
3. Bar-On Emotional Quotient Inventory (EQi)
4. Self-Rated Emotional Intelligence Scale (SREIS)
5. Memory Suppression Task Training (2-4 Trials)
6. Memory Suppression Phases: A, B, C
7. Positive and Negative Affect Schedule (PANAS)
8. Memory Suppression Task-Suppression (4^{th} phase) (MST1)
9. Memory Suppression Recall (MST2; NO SCANNING)
10. Memory Suppression Task-Face Interference (MST3)
11. Memory Suppression Task-Scene Interference (MST4)
12. Emotional Distraction Task (EDT)
13. Social Dominance Task (SDT)
14. Food Perception Task (FPT)
15. Food/Activity Decision Task (FDT)
16. BMAT Anger
17. BMAT Fear
18. BMAT Happy
19. BMAT Trustworthy
20. Overt Trustworthiness Task (OTT)
21. Resting fMRI
22. Memory Suppression Task Post Test
23. Emotion Distraction Post Test
24. Masked Affect Post Test
25. Food Recognition Post Test
26. Food Ratings
27. Barratt Impulsivity Scale (BIS11)
28. Connor-Davidson Resilience Scale (CD-RISC)
29. Invincibility Belief Index (IBI)

30. Evaluation of Risks Questionnaire (EVAR)
31. Brief Sensation Seeking Scale (BSSS)
32. Happy Chimeric Test (CFT)
33. Sad Chimeric Test (CFT)
34. Balloon Analogue Risk Task (BART)
35. Ekman 60 Face Test (60 FT)
36. Wechsler Abbreviated Scale of Intelligence (WASI)
37. Karolinska Airport Trustworthiness Test (KATT)
38. Intuition Test
39. Facial Assessment of Trustworthiness Test (FATT)
40. Design Organization Test (DOT) – FORM A and B
41. Iowa Gambling Task (IGT)
42. Revised NEO Personality Inventory (NEO-PI-R)
43. Anxiety Sensitivity Index (ASI)
44. Morningness-Eveningness Questionnaire (MEQ)
45. Courtauld Emotion Control Scale (CECS)
46. Beck Depression Inventory (BDI)
47. Trust Go/NoGo (Form A or X)/Trust Go/NoGo Reversed (Form B or Y)
48. Personality Assessment Inventory (PAI)
49. Humor Appreciation Test (HAT)
50. Global Assessment Tool (GAT)

Curriculum Vitae

Date Prepared: **October 11, 2012**

Name: WILLIAM DALE (SCOTT) KILLGORE

Office Address: Neuroimaging Center
McLean Hospital

Belmont, MA 02478 United States

Work Email: killgore@mclean.harvard.edu

Education

1985	A.A. (Liberal Arts), San Antonio College
1985	A.A.S (Radio-TV-Film), San Antonio College
1990	B.A. (Psychology), Summa cum laude with Distinction, University of New Mexico
1992	M.A. (Clinical Psychology), Texas Tech University
1996	PH.D. (Clinical Psychology), Texas Tech University

Postdoctoral Training

08/95-07/96	Predoctoral Fellow, Clinical Psychology, Yale School of Medicine
08/96-07/97	Postdoctoral Fellow, Clinical Neuropsychology, University of OK Health Sciences Center
08/97-07/99	Postdoctoral Fellow, Clinical Neuropsychology, University of Pennsylvania Medical School
07/99-09/00	Research Fellow, Neuroimaging, McLean Hospital/ Harvard Medical School

Faculty Academic Appointments

10/00-08/02	Instructor in Psychology in the Department of Psychiatry Harvard Medical School, Boston, MA
09/02-07/07	Clinical Instructor in Psychology in the Department of Psychiatry Harvard Medical School, Boston, MA
08/07-10/10	Instructor in Psychology in the Department of Psychiatry Harvard Medical School, Boston, MA
04/08-	Faculty Affiliate, Division of Sleep Medicine Harvard Medical School, Boston, MA
10/10-10/12	Assistant Professor of Psychology in the Department of Psychiatry

Harvard Medical School, Boston, MA
10/12- Associate Professor of Psychology in the Department of Psychiatry
Harvard Medical School

Appointments at Hospitals/Affiliated Institutions

10/00-08/02 Assistant Research Psychologist, McLean Hospital, Belmont, MA
08/02-07/04 Research Psychologist, Department of Behavioral Biology, Walter Reed Army Institute of Research, Silver Spring, MD
09/02-04/05 Special Volunteer, National Institute on Deafness and Other Communication Disorders (NIDCD), National Institutes of Health (NIH), Bethesda, MD
09/02-07/07 Consultant in Psychology, McLean Hospital, Belmont, MA
08/07- Research Psychologist, McLean Hospital, Belmont, MA

Other Professional Positions

11/01-08/02 First Lieutenant, Medical Service Corps, United States Army Reserve (USAR)
08/02-07/05 Captain, Medical Service Corps, United States Army
08/05-10/07 Major, Medical Service Corps, United States Army
10/07-07/12 Major, Medical Service Corps, United States Army Reserve (USAR)
10/07-3/10 Chief Psychologist, GovSource, Inc., U.S. Department of Defense Government Contractor
08/08- Consulting Psychologist, The Brain Institute, University of Utah
07/12- Lieutenant Colonel, Medical Service Corps, United States Army Reserve (USAR)

Major Administrative Leadership Positions

Local

1988-1989 Undergraduate Teaching Assistant-Introduction to Psychology 102, University of New Mexico

1990-1991 Graduate Teaching Assistant-General Psychology 1300, Texas Tech University

1991-1992 Graduate Teaching Assistant-Psychology of Learning Laboratory 3317, Texas Tech University

2004-2007 Chief, Neurocognitive Performance Branch, Walter Reed Army Institute of Research, Silve Spring, MD

2005-2006 Neuropsychology Postdoctoral Program Training Supervisor, Walter Reed Hospital, Washington, DC

2011- Co-Director, Social, Cognitive, and Affective Neuroscience Laboratory, McLean Hospital, Belmont, MA

Committee Service

Local

2003 Scientific Review Committee, Walter Reed Army Institute of Research (WRAIR), Silver Spring, MD

2005 Scientific Review Committee, Walter Reed Army Institute of Research (WRAIR), Silver Spring, MD

Regional

2005-2006 Undergraduate Honors Thesis Committee, Jessica Richards [Chairperson], University of Maryland, Baltimore County

2011 Scientific Review Committee, U.S. Army Institute of Environmental Medicine (USARIEM), Natick, MA

National

2011- National Network of Depression Centers, Military Task Group

International

2005-2006 Doctoral Thesis Committee, Belinda J. Liddell, University of Sydney, Australia

Professional Societies

1995-1997 American Psychological Association, Member

1998-2000 National Academy of Neuropsychology, Member

2012- American Academy of Sleep Medicine, Member

Grant Review Activities

National

2004 University of Alabama, Clinical Nutrition Research Center (UAB CNRC) Pilot/Feasibility Study Program Review Committee

2006 U.S. Small Business Administration, Small Business Technology Transfer (STTR) Program Review Committee

2006 Cognitive Performance Assessment Program Area Steering Committee, U.S. Army Military Operational Medicine Research Program Funding Panel

2007 Cognitive Performance Assessment Program Area Steering Committee, U.S. Army Military Operational Medicine Research Program Funding Panel

2008 United States Army Medical Research and Materiel Command (USAMRMC) Congressionally Directed Medical Research Programs (CDMRP) Extramural Grant Review Panel

2009 NIH-CSR Brain Disorders and Clinical Neuroscience N02 Member Study Conflict Section Review Panel

2009 Sleep Physiology and Fatigue Interventions Program Area Steering Committee, U.S. Army Military Operational Medicine Research Program

2011 National Science Foundation (NSF) Grant Reviewer

2012 National Science Foundation (NSF) Grant Reviewer

International

2009	Scotland, UK, Biomedical and Therapeutic Research Committee, Grant Reviewer
2010	Canada, Social Sciences and Humanities Research Council of Canada, Grant Reviewer
2011	Israel, Israel Science Foundation (ISF), Grant Reviewer

Editorial Activities

2001-2011	Reviewer, Psychological Reports
2001-2011	Reviewer, Perceptual and Motor Skills
2002	Reviewer, American Journal of Psychiatry
2002-2009	Reviewer, Biological Psychiatry
2003	Reviewer, Clinical Neurology and Neurosurgery
2004	Reviewer, NeuroImage
2004-2006	Reviewer, Neuropsychologia
2004	Reviewer, Journal of Neuroscience
2004	Reviewer, Consciousness and Cognition
2005	Reviewer, Experimental Brain Research
2005	Reviewer, Schizophrenia Research
2005-2012	Reviewer, Archives of General Psychiatry
2005	Reviewer, Behavioral Brain Research
2005-2009	Reviewer, Human Brain Mapping
2005-2006	Reviewer, Psychiatry Research: Neuroimaging
2006	Reviewer, Journal of Abnormal Psychology
2006	Reviewer, Psychopharmacology
2006	Reviewer, Developmental Science
2006	Reviewer, Acta Psychologica
2006	Reviewer, Neuroscience Letters
2006-2011	Reviewer, Journal of Sleep Research
2006-2007	Reviewer, Physiology and Behavior
2006-2011	Reviewer, SLEEP
2007	Reviewer, Journal of Clinical and Experimental Neuropsychology
2008	Reviewer, European Journal of Child and Adolescent Psychiatry
2008	Reviewer, Judgment and Decision Making
2008-2010	Reviewer, Aviation, Space, & Environmental Medicine
2008	Reviewer, Journal of Psychophysiology
2008	Reviewer, Brazilian Journal of Medical and Biological Research
2008	Reviewer, The Harvard Undergraduate Research Journal
2008	Reviewer, Bipolar Disorders
2008-2010	Reviewer, Chronobiology International
2008	Reviewer, International Journal of Obesity
2009	Reviewer, European Journal of Neuroscience
2009-2012	Reviewer, International Journal of Eating Disorders
2009	Reviewer, Psychophysiology
2009	Reviewer, Traumatology
2009	Reviewer, Clinical Medicine: Therapeutics
2009	Reviewer, Acta Pharmacologica Sinica
2009	Reviewer, Collegium Antropologicum

2009	Reviewer, Journal of Psychopharmacology
2009-2010	Reviewer, Obesity
2009	Reviewer, Scientific Research and Essays
2009	Reviewer, Child Development Perspectives
2009-2010	Reviewer, Personality and Individual Differences
2009-2010	Reviewer, Noise and Health
2009-2010	Reviewer, Sleep Medicine
2010	Reviewer, Nature and Science of Sleep
2010	Reviewer, Psychiatry and Clinical Neurosciences
2010	Reviewer, Learning and Individual Differences
2010	Reviewer, Cognitive, Affective, and Behavioral Neuroscience
2010	Reviewer, BMC Medical Research Methodology
2010-2011	Reviewer, Journal of Adolescence
2010-2012	Reviewer, Brain Research
2011	Reviewer, Brain
2011	Reviewer, Social Cognitive and Affective Neuroscience
2011	Reviewer, Journal of Traumatic Stress
2011	Reviewer, Social Neuroscience
2011	Reviewer, Brain and Cognition
2011	Reviewer, Frontiers in Neuroscience
2011-2012	Reviewer, Sleep Medicine Reviews
2012	Reviewer, Journal of Experimental Psychology: General
2012	Reviewer, Ergonomics
2012	Reviewer, Behavioral Sleep Medicine
2012	Reviewer, Neuropsychology
2012	Reviewer, Emotion
2012	Reviewer, JAMA
2012	Reviewer, BMC Neuroscience
2012	Reviewer, Cognition and Emotion
2012	Reviewer, Journal of Behavioral Decision Making
2012	Reviewer, Psychosomatic Medicine
2012	Reviewer, PLoS One

Other Editorial Roles

2009-	Editorial Board Member	International Journal of Eating Disorders
2012-	Editor	Datasets in Neuroscience
2012-	Editor	Datasets in Medicine
2012-	Editor	Journal of Sleep Disorders: Treatment and Care

Honors and Prizes

1990	Outstanding Senior Honors Thesis in Psychology, University of New Mexico
1990-1995	Maxey Scholarship in Psychology, Texas Tech University
2001	Rennick Research Award, Co-Authored Paper, International

	Neuropsychological Society
2002	Honor Graduate, AMEDD Officer Basic Course, U.S. Army Medical Department Center and School
2002	Lynch Leadership Award Nominee, AMEDD Officer Basic Course, U.S. Army Medical Department Center and School
2003	Outstanding Research Presentation Award, 2003 Force Health Protection Conference, U.S. Army Center for Health Promotion and Preventive Medicine
2005	Edward L. Buescher Award for Excellence in Research by a Young Scientist, Walter Reed Army Institute of Research (WRAIR) Association
2009	Merit Poster Award, International Neuropsychological Society
2009	Outstanding Research Presentation Award, 2009 Force Health Protection Conference, U.S. Army Center for Health Promotion and Preventive Medicine
2010	Best Paper Award, Neuroscience, 27th U.S. Army Science Conference
2011	Published paper included in *Best of Sleep Medicine 2011*
2011	Blue Ribbon Finalist, 2011 Top Poster Award in Clinical and Translational Research, Society of Biological Psychiatry
2012	Defense Advance Research Projects Agency (DARPA) Young Faculty Award in Neuroscience

Report of Funded and Unfunded Projects

Funding Information

Past

2001-2003	fMRI of Unconscious Affect Processing in Adolescence. N.I.H., 1R03HD41542-01 P.I.: Killgore ($79,000.)
2003-2006	The Effects of Sleep-Loss and Stimulant Countermeasures on Judgment and Decision Making. U.S. Army Medical Research and Materiel Command (USAMRMC) Competitive Medical Research Proposal Program (CMRP), P.I.: Killgore (Total Award: $1,345,000.)
2004-2005	Sleep/wake Schedules in 3ID Aviation Brigade Soldiers. Defense Advanced Research Projects Agency (DARPA) P.I.: Killgore (Total Award: $60,000.)
2005-2006	Functional Neuroimaging Studies of Neural Processing Changes with Sleep and Sleep Deprivation. U.S. Army Medical Research and Materiel Command (USAMRMC) Task Area C (Warfighter Judgment and Decision Making) Program Funding P.I.: Killgore (Total Award: $219,400.)
2006-2007	Establishing Normative Data Sets for a Series of Tasks to Measure the Cognitive Effects of Operationally Relevant Stressors. U.S. Army Medical Research and Materiel Command (USAMRMC) Task Area C (Warfighter Judgment and Decision Making) Program Funding, P.I.: Killgore (Total Award:$154,000.)

2006-2007 Military Operational Medicine Research Program (MOM-RP), Development of the Sleep History and Readiness Predictor (SHARP).
U.S. Army Medical Research and Materiel Command (USAMRMC)
P.I.: Killgore (Total Award:$291,000.)

Current

2009-2012 The Neurobiological Basis and Potential Modification of Emotional Intelligence through Affective Behavioral Training.
U.S. Army Medical Research and Materiel Command (USAMRMC),
P.I.: Killgore (Total Award: $414,461.)
Major Goal: To identify the neurobiological basis of cognitive and emotional intelligence using functional and structural magnetic resonance imaging.

2011-2014 Effects of Bright Light Therapy on Sleep, Cognition, and Brain Function following Mild Traumatic Brain Inju
U.S. Army Medical Research and Materiel Command (USAMRMC),
P.I.: Killgore (Total Award: $754,040)
Major Goal: To evaluate the effectiveness of morning exposure to bright light as a treatment for improving in sleep patterns among individuals with post-concussive syndrome. Effects of improved sleep on recovery due t this treatment will be evaluated using neurocognitive testing as well as functional and structural neuroimaging.

2012-2015 Internet Based Cognitive Behavioral Therapy Effects on Depressive Cognitions and Brain function.
U.S. Army Medical Research and Materiel Command (USAMRMC),
Co-PI: Killgore (Total Award: $1,646,045)
Major Goal: To evaluate the effectiveness of an internet-based cognitive behavioral therapy treatment program on improving depressive symptoms, coping and resilience skills, cognitive processing and functional brain activation patterns within the prefrontal cortex.

2012-2014 Defense Advance Research Projects Agency (DARPA) Young Faculty Award in Neuroscience
P.I.: Killgore (Total Award: $297,021)
Major Goal: To combine several neuroimaging techniques, including functional and structural magnetic resonance imaging, diffusion tensor imaging, and magnetic resonance spectroscopy to predict individual resilience to 24 hours of sleep deprivation.

2012-2016 Congressionally Directed Medical Research Program (CDMRP), Psychological Health/Traumatic Brain Injury (PH/TBI) Research Program: Applied Neurotrauma Research Award
DoD CDMRP
P.I.: Killgore (Total Award: $2,272,098)
Major Goal: To evaluate the relation between axonal damage and neurocognitive performance in patients with traumatic brain injury at multiple points over the recovery trajectory, in order to predict recovery.

Report of Local Teaching and Training

Laboratory and Other Research Supervisory and Training Responsibilities

2005-2006 1 Fellow for 250 hrs/year, Neuropsychology Postdoctoral Research Training Program Supervisor, Walter Reed Hospital

2011- 2 Fellows for 2080 hrs/year, Harvard Research Fellow Supervisor, McLean Hospital

Formally Supervised Trainees

1997-1999 David Glahn, Ph.D. Associate Professor, Yale University School of Medicine

Provided mentorship in clinical neuropsychological assessment and research at the University of Pennsylvania Hospital, which resulted in the development of a new psychometric test, 1 co-authored published conference abstract, and 1 co-authored published journal article.

1997-1999 Daniel Casasanto, Ph.D. Senior Scientist/Lecturer, Max Plank Institute for Psycholinguistics

Supervised this trainee while at the University of Pennsylvania Hospital, which resulted in the development of a new psychometric test, 9 co-authored published conference abstracts, and 5 co-authored published journal articles.

2002-2005 Alexander Vo, Ph.D. Associate Professor, UTMB; Vice President, Electronically Mediated Services, Colorado Access

Served as one of his research mentors at the Walter Reed Army Institute of Research, which resulted in 3 co-authored published conference abstracts, and 3 co-authored published journal articles.

2002-2007 Rebecca Reichardt, M.A. Human Subjects Protection Scientist, USAMRMC

Supervised her research training in my lab at the Walter Reed Army Institute of Research, which resulted in 10 co-authored published conference abstracts, and 2 co-authored published journal articles.

2003-2004 Stan Liu, M.D. Medical Intern, Johns Hopkins Medical School

Supervised his research training in my lab at the Walter Reed Army Institute of Research, which primarily involved training in neuropsychological assessment and sleep research methods.

2003-2004 Neil Arora, B.A. Student, Yale University

Supervised his research project in my lab at the Walter Reed Army Institute of Research and NIH, which primarily involved training in brain imaging analysis and led to 2 co-authored published conference abstracts.

2003-2005 Nancy Grugle, Ph.D. Assistant Professor, Cleveland State University

Supervised her Doctoral Dissertation research project in my lab at the Walter Reed Army Institute of Research, which resulted in 23 co-authored published conference abstracts, and 10 co-authored published journal articles.

2003-2005 Joshua Bailey, B.A. Seminary Student

Supervised his computer programing development and research in my lab at the Walter Reed Army Institute of Research, which resulted in 1 co-authored published conference abstract, and 1 co-authored computer analysis package submitted for U.S. patent.

2003-2006 Athena Kendall, M.A. Lab Manager, Walter Reed Army Medical Center

Supervised part of her masters degree research project and other research work in my lab at the Walter Reed Army Institute of Research, which resulted in 4 co-authored published conference abstracts, and 4 co-authored published journal articles.

2003-2006 Lisa Day, M.S.W. Clinical Social Worker, Washington D.C.

Supervised her research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 3 co-authored published conference abstracts, and 1 co-authored published journal article.

2004-2005 Merica Shepherd, B.A. Laboratory Coordinator

Supervised her research training in my lab at the Walter Reed Army Institute of Research, which primarily involved training in neuropsychological assessment and sleep research methods.

2004-2005 Cynthia Hawes, B.A. Research Program Coordinator

Supervised her research training in my lab at the Walter Reed Army Institute of Research, which primarily involved training in neuropsychological assessment and sleep research methods.

2004-2006 Christopher Li, B.A. Graduate Student

Supervised his research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 3 co-authored published conference abstracts, and 1 co-authored published journal article.

2004-2007 Jessica Richards, M.S. Ph.D. Student, University of Maryland College Park

Served as Chair of her Senior Honors Thesis Committee and supervised her research work in my lab at the Walter Reed Army Institute of Research, which resulted in 8 co-authored published conference abstracts, a senior honors thesis, and 2 co-authored published journal articles.

2004-2007 Erica Lipizzi, M.A. Graduate Student, Emory University

Supervised her research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 16 co-authored published conference abstracts, and 12 co-authored published journal articles.

2004-2007 Brian Leavitt, B.S. Research Technician, Walter Reed Army Institute of Research

Supervised his research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 4 co-authored published conference abstracts, and 1 co-authored published journal article.

2004-2007 Rachel Newman, M.S. Senior Laboratory Manager, Walter Reed

Supervised her research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 6 co-authored published conference abstracts, and 1 co-authored published journal article.

2004-2007 Alexandra Krugler, B.S. Medical Student, Louisiana State University

Supervised her research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 5 co-authored published conference abstracts, and 1 co-authored published journal article.

2005 Amy Conrad, PH.D. Clinical Psychologist, Washington D.C.

Supervised her research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 4 co-authored published conference abstracts, and 1 co-authored published journal article.

2005-2006 Nathan Huck, PH.D. Clinical Neuropsychologist, Walter Reed Army Institute of Research

Served as his post-doctoral research training supervisor at the Walter Reed Army Institute of Research, which resulted in 1 co-authored published conference abstract and 1 co-authored published journal article.

2005-2006 Ellen Kahn-Greene, Ph.D. Post-Doctoral Fellow, Boston VA

Supervised her research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 7 co-authored published conference abstracts and 5 co-authored published journal articles.

2005-2006 Alison Muckle, B.A. Research Technician

Supervised her research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 1 co-authored published conference abstract and 1 co-authored published journal article.

2005-2006 Christina Murray, B.S. Medical Student, Drexel University

Supervised her research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 2 co-authored published conference abstracts.

2005-2007 Gautham Ganesan, M.D. Medical Student, UC Irvine

Supervised his research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 1 co-authored published conference abstract and 1 co-authored published journal article.

2005-2007 Dante Picchioni, Ph.D. Research Psychologist, Walter Reed Army Institute of Research

Supervised part of his post-doctoral brain imaging research training at the Walter Reed Army Institute of Research, which resulted in 1 co-authored published conference abstract and 1 co-authored published journal article.

2006-2007 Tracy Rupp, Ph.D. Research Psychologist, Walter Reed Army Institute of Research

Supervised part of her post-doctoral sleep research training at the Walter Reed Army Institute of Research, which resulted in 17 co-authored conference abstracts and 2 co-authored published journal articles.

2006-2007 Kacie Smith, B.A. Study Manager, Walter Reed Army Institute of Research

Supervised her research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 7 co-authored published conference abstracts.

2006-2007 Shane Smith, B.S. Medical Student, University of the West Indies

Served as his research mentor at the Walter Reed Army Institute of Research, which primarily involved training in neuropsychological assessment and sleep research methods.

2006-2007 Shanelle McNair Research Technician, Walter Reed Army Institute of Research

Supervised her research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 1 co-authored published article.

2006-2007 George Watlington Research Technician, Walter Reed Army Institute of Research

Supervised his research training and work in my lab at the Walter Reed Army Institute of Research, which resulted in 1 co-authored published article.

2008 Grady O'Brien Undergraduate Student

Served as his summer volunteer research mentor at McLean Hospital, which resulted in 1 oral research presentation

2008-2009 Alex Post Undergraduate Student, Carnegie Mellon University

Served as his summer volunteer research mentor at McLean Hospital, which resulted in 2 oral research presentations and 1 co-authored published abstract.

2008-2009 Lauren Price, B.A. Senior Clinical Research Assistant, McLean Hospital

Supervised her research training and work in my lab at the McLean Hospital, which resulted in 11 co-authored published conference abstracts and 4 co-authored published articles.

2009- Zachary Schwab, B.S. Research Assistant, McLean Hospital
Supervised his research training and work in my lab at the McLean Hospital, which resulted in 52 co-authored published conference abstracts and 4 co-authored published articles.

2009-2011 Melissa Weiner, B.S. Graduate Student, Yale School of Public Health
Supervised her research training and work in my lab at the McLean Hospital, which resulted in 32 co-authored published conference abstracts and 2 co-authored published articles.

2010-2011 Norah Simpson, Ph.D. Post-Doctoral Fellow, Beth Israel Deaconess/Harvard Medical School
Served as a research mentor on her federal K-Award grant application.

2010-2012 Vincent Capaldi, M.D. Medical Resident, Walter Reed Army Medical Ctr.
Served as his post-doctoral research mentor, which resulted in 1 co-authored published conference abstract and 2 co-authored published articles.

2010-2011 Christina Song Undergraduate Student, Smith College
Served as her summer volunteer research mentor at McLean Hospital, which resulted in 1 co-authored published abstract.

2011 Jill Kizielewicz Undergraduate Student, Hamilton College
Served as her summer volunteer research mentor at McLean Hospital, which resulted in 1 co-authored published abstract.

2011- Sophie DelDonno, B.A. Research Assistant, McLean Hospital
Supervised her research training and work in my lab at the McLean Hospital, which resulted in 14 co-authored published conference abstracts and 2 co-authored published articles.

2011- Maia Kipman, B.A. Research Assistant, McLean Hospital
Supervised her research training and work in my lab at the McLean Hospital, which resulted in 14 co-authored published conference abstracts and 2 co-authored published articles.

2011 Michael Covell, B.A. Graduate Student, Baruch College
Served as one of his research mentors at McLean Hospital, which resulted in 3 co-authored published conference abstracts.

2011- Mareen Weber, Ph.D. Post-Doctoral Fellow, Harvard Medical School
Supervised her post-doctoral research training and work in my lab at the McLean Hospital, which has resulted in 9 co-authored published conference abstracts, 1 travel award, 2 co-authored published articles, five federal grant submissions, and 2 successfully funded grants.

2012- Julia Cohen, Ph.D. Post-Doctoral Fellow, Harvard Medical School
Served as one of her research mentors at McLean Hospital, which resulted in 2 co-authored published conference abstracts.

2012- Christian Webb, Ph.D. Post-Doctoral Fellow, Harvard Medical School
Currently supervising his post-doctoral research training and work in my lab at the McLean Hospital.

Local Invited Presentations

2000 The Neurobiology of Emotion in Children, McLean Hospital
Lecturer: 30 participants, 2 hours contact time per year, 10 hours prep time per year.
[Invited Lecture]

2001 The Neurobiology of Emotion in Children and Adolescents, McLean Hospital
Lecturer: 60 participants, 2 hours contact time per year, 10 hours prep time per year.
[Invited Lecture]

2001 Using Functional MRI to Study the Developing Brain, Judge Baker Children's Center
Lecturer: 8 participants, 2 hours contact time per year, 10 hours prep time per year *[Invited Seminar]*

2005 Briefing to the Chairman of the Congressional Committee on Strategies to Protect the Health of Deployed U.S. Forces, John H. Moxley, on the Optimization of Judgment and Decision Making Capacities in Soldiers Following Sleep Deprivation, Walter Reed Army Institute of Research, Washington, DC*[Invited Lecture]*

2005 Lecture on Functional Neuroimaging, Cognitive Assessment, and the Enhancement of Soldier Performance, Walter Reed Army Institute of Research, Washington, DC *[Invited Lecture]*

2006 Lecture on Optimization of Judgment and Decision Making Capacities in Soldiers Following Sleep Deprivation, Brain Imaging Center, McLean Hospital, Belmont MA *[Invited Lecture]*

2006 Briefing to the Chairman of the Cognitive Performance Assessment Program Area Steering Committee, U.S. Army Military Operational Medicine Research Program, entitled Optimization of Judgment and Decision Making Capacities in Soldiers Following Sleep Deprivation, Walter Reed Army Institute of Research *[Invited Lecture]*

2010 Lecture on Patterns of Cortico-Limbic Activation Across Anxiety Disorders, Center for Anxiety, Depression, and Stress, McLean Hospital, Belmont, MA *[Invited Lecture]*

2010 Lecture on Cortico-Limbic Activation Among Anxiety Disorders, Neuroimaging Center, McLean Hospital, Belmont, MA *[Invited Lecture]*

2011 Lecture on Shared and Differential Patterns of Cortico-Limbic Activation Across Anxiety Disorders, McLean Research Day Brief Communications, McLean Hospital, Belmont, MA *[Invited Lecture]*

2012 Briefing to GEN (Ret) George Casey Jr., former Chief of Staff of the U.S. Army, entitled Research for the Soldier. McLean Hospital, Belmont, MA. *[Invited Lecture]*

Report of Regional, National and International Invited Teaching and Presentations

Invited Presentations and Courses

Regional

2002 Cortico-Limbic Activation in Adolescence and Adulthood, Youth Advocacy Project, Cape Cod, MA
Lecturer: 45 participants, 2 hours contact time per year, 10 hours prep time per year
[Invited Lecture]

2006 Lecture on Norming a Battery of Tasks to Measure the Cognitive Effects of Operationally Relevant Stressors, Cognitive Performance Assessment Program Area Steering Committee, U.S. Army Military Operational

Medicine Research Program, Washington, DC*[Invited Lecture]*

2007 Lecture on Cerebral Responses During Visual Processing of Food, U.S. Army Institute of Environmental Medicine, Natick, MA*[Invited Lecture]*

2007 Briefing on the Measurement of Sleep-Wake Cycles and Cognitive Performance in Combat Aviators, U.S. Department of Defense, Defense Advanced Research Projects Agency (DARPA), Washington, DC

2008 Lecture on Sleep Deprivation, Executive Function, and Resilience to Sleep Loss; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2008 Lecture on the Role of Research Psychology in the Army; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA*[Invited Lecture]*

2008 Lecture on Combat Stress Control: Basic Battlemind Training; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA*[Invited Lecture]*

2009 Lecture entitled Evaluate a Casualty, Prevent Shock, and Prevent Cold Weather injuries; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA*[Invited Lecture]*

2009 Lecture on Combat Exposure and Sleep Deprivation Effects on Risky Decision-Making; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2009 Lecture on the Sleep History and Readiness Predictor (SHARP); 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2009 Lecture on The Use of Actigraphy for Measuring Sleep in Combat and Military Training; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2010 Lecture entitled Casualty Evaluation; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2010 Lecture entitled Combat Stress and Risk-Taking Behavior Following Deployment; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2010 Lecture entitled Historical Perspectives on Combat Medicine at the Battle of Gettysburg; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2010 Lecture entitled Sleep Loss, Stimulants, and Decision-Making; 105th IMA

Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2010 Lecture entitled PTSD: New Insights from Brain Imaging; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2011 Lecture entitled Effects of bright light therapy on sleep, cognition and brain function after mild traumatic brain injury; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2011 Lecture entitled Laboratory Sciences and Research Psychology in the Army; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2011 Lecture entitled Tools for Assessing Sleep in Military Settings; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2011 Lecture entitled The Brain Basis of Emotional Trauma and Practical Issues in Supporting Victims of Trauma, U.S. Department of Justice, United States Attorneys Office, Serving Victims of Crime Training Program, Holyoke, MA *[Invited Lecture]*

2011 Lecture entitled The Brain Altering Effects of Traumatic Experiences; 105th Reinforcement Training Unit (RTU), U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2012 Lecture entitled Sleep Loss, Caffeine, and Military Performance; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

2012 Lecture entitled Using Light Therapy to Treat Sleep Disturbance Following Concussion; 105th IMA Detachment, U.S. Army Reserve Center, Boston, MA *[Invited Lecture]*

National

2000 Lecture on the Neurobiology of Emotional Development in Children, 9th Annual Parents as Teachers Born to Learn Conference, St. Louis, MO *[Invited Lecture]*

2002 Lecture on the Changes in the Lateralized Structure and Function of the Brain during Adolescent Development, Walter Reed Army Institute of Research, Washington, DC*[Invited Lecture]*

2004 Lecture on Sleep Deprivation, Cognition, and Stimulant Countermeasures: Seminar Presented at the Bi-Annual 71F Research Psychology Short Course, Ft. Detrick, MD, U.S. Army Medical Research and Materiel Command *[Invited Lecture]*

2004 Lecture on the Regional Cerebral Blood Flow Correlates of Electroencephalographic Activity During Stage 2 and Slow Wave Sleep: An H215O PET Study: Presented at the Bi-Annual 71F Research Psychology Short Course, Ft. Detrick, MD, U.S. Army Medical Research and Materiel Command*[Invited Lecture]*

2004 Oral Platform Presentation: Regional cerebral metabolic correlates of electroencephalographic activity during stage-2 and slow-wave sleep: An H215O PET Study, 18th Associated Professional Sleep Societies Annual Meeting, Philadelphia, PA.

2005 Lecture on The Sleep History and Readiness Predictor: Presented to the Medical Research and Materiel Command, Ft. Detrick, MD,*[Invited Lecture]*

2006 Lecture on The Sleep History and Readiness Predictor: Presented at the Bi-Annual 71F Research Psychology Short Course, Ft. Rucker, AL, U.S. Army Medical Research and Materiel Command*[Invited Lecture]*

2007 Lecture on the Effects of Fatigue and Pharmacological Countermeasures on Judgment and Decision-Making, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL *[Invited Lecture]*

2008 Lecture on the Validation of Actigraphy and the SHARP as Methods of Measuring Sleep and Performance in Soldiers, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL*[Seminar]*

2009 Lecture on Sleep Deprivation, Executive Function, and Resilience to Sleep Loss: Walter Reed Army Institute of Research AIBS Review, Washington DC*[Invited Lecture]*

2009 Lecture Entitled: Influences of Combat Exposure and Sleep Deprivation on Risky Decision-Making, Evans U.S. Army Hospital, Fort Carson, CO*[Invited Lecture]*

2009 Lecture on Making Bad Choices: The Effects of Combat Exposure and Sleep Deprivation on Risky Decision-Making, 4th Army, Division West, Quarterly Safety Briefing to the Commanding General and Staff, Fort Carson, CO*[Invited Lecture]*

2009 Symposium on Sleep Deprivation, Judgment, and Decision-Making, 23rd Annual Meeting of the Associated Professional Sleep Societies, Seattle, WA*[Invited Lecture]*

2009 Symposium Session Moderator: Workshop on Components of Cognition and Fatigue: From Laboratory Experiments to Mathematical Modeling and Operational Applications, Washington State University, Spokane, WA*[Invited Speaker]*

2009 Lecture on Comparative Studies of Stimulant Action as Countermeasures for Higher Order Cognition and Executive Function Impairment that Results from Disrupted Sleep Patterns, Presented at the NIDA-ODS Symposium entitled: Caffeine: Is the Next Problem Already Brewing, Rockville, MD *[Invited Lecture]*

2010 Oral Platform Presentation: Sleep deprivation selectively impairs emotional

aspects of cognitive functioning, 27th Army Science Conference, Orlando, FL.

2010 Oral Platform Presentation: Exaggerated amygdala responses to masked fearful faces are specific to PTSD versus simple phobia, 27th Army Science Conference, Orlando, FL.

2011 Lecture Entitled: The effects of emotional intelligence on judgment and decision making, Military Operational Medicine Research Program Task Area C, R & A Briefing, Walter Reed Army Institute of Research, Silver Spring, MD *[Invited Lecture]*

2011 Lecture Entitled: Effects of bright light therapy on sleep, cognition, brain function, and neurochemistry following mild traumatic brain injury, Military Operational Medicine Research Program Task Area C, R & A Briefing, Walter Reed Army Institute of Research, Silver Spring, MD *[Invited Lecture]*

2012 Oral Symposium Presentation: Shared and distinctive patterns of cortico-limbic activation across anxiety disorders, 32nd Annual Conference of the Anxiety Disorders Association of America, Arlington, VA.

2012 Lecture Entitled: Effects of bright light therapy on sleep, cognition, brain function, and neurochemistry following mild traumatic brain injury, Military Operational Medicine Research Program In Progress Review (IPR) Briefing, U.S. Army Medical Research and Materiel Command, Fort Detrick, MD *[Invited Lecture]*

International

1999 Oral Platform Presentation: Functional MRI lateralization during memory encoding predicts seizure outcome following anterior temporal lobectomy, 27th Annual Meeting of the International Neuropsychological Society, Boston, MA.

2001 Oral Platform Presentation: Sex differences in functional activation of the amygdala during the perception of happy faces, 29th Annual Meeting of the International Neuropsychological Society, Chicago, IL.

2002 Oral Platform Presentation: Developmental changes in the lateralized activation of the prefrontal cortex and amygdala during the processing of facial affect, 30th Annual Meeting of the International Neuropsychological Society, Toronto, Ontario, Canada.

2002 Oral Platform Presentation: Gray and white matter volume during adolescence correlates with cognitive performance: A morphometric MRI study, 30th Annual Meeting of the International Neuropsychological Society, Toronto, Ontario, Canada.

2007 Symposium on Cortical and Limbic Activation in Response to Visual Images of Low and High-Caloric Foods, 6th Annual Meeting of the International Society for Behavioral Nutrition and Physical Activity (ISBNPA), Oslo, Norway *[Invited Lecture]*

2008 Lecture on Sleep Deprivation, Executive Function, & Resilience to Sleep Loss, First Franco-American Workshop on War Traumatism, IMNSSA, Toulon, France *[Invited Lecture]*

2012 Oral Platform Presentation: Shared and unique patterns of cortico-limbic activation across anxiety disorders. 40th Meeting of the International Neuropsychological Society, Montreal, Canada.

Report of Clinical Activities and Innovations

Current Licensure and Certification

2001- Clinical Psychologist, New Hampshire

Practice Activities

1991-1995 Psychology, Clinical, Psychology Clinic, Texas Tech University, Lubbock, TX
Clinical Activity Description: Provided psychotherapy and other supervised psychological services for a broad spectrum of client problems. Duties included regular therapy contacts with four to eight clients per week for approximately four years. Clients ranged in age from preschool through middle age. Clinical responsibilities included intake evaluations, formal testing and assessment, case formulation and treatment plan development, and delivery of a wide range of psychotherapy services including crisis intervention, behavior modification, short-term cognitive restructuring, and long-term psychotherapy.
Patient Load: 6/week

1993-1995 Psychology, Neuropsychology, Methodist Hospital Rehabilitation Institute, Lubbock, TX
Clinical Activity Description: A two year placement consisting of two days per week within a large rehabilitation unit of a major regional medical center. Responsibilities included administration, scoring, and writing of neuropsychological assessments/reports, primarily emphasizing the Halstead-Reitan Neuropsychological Battery. Assessment services were provided on both inpatient and outpatient basis.
Patient Load: 2/week

1995-1996 Psychology, Neuropsychology, Yale University School of Medicine, Connecticut Mental Health Center
Clinical Activity Description: Neuropsychological and psychodiagnostic assessment of chronic and severe mentally ill patients. Duties included patient interviewing, test administration, scoring, interpretation, and report writing. Assessment and consultation services were provided for both the inpatient and outpatient units.

Patient Load: 2/week

1995-1996 Psychology, Clinical, Yale University School of Medicine, West Haven Mental Health Clinic
Clinical Activity Description: Provided short-term, long-term, and group psychotherapy services, consultation, and psychological assessments for adults, children, and families. Duties also included co-leading a regular outpatient group devoted to treatment of moderate to severe personality disorders.
Patient Load: 12/week

1996-1997 Psychology, Neuropsychology, University of Oklahoma Health Sciences Center
Clinical Activity Description: Full-time placement in the Neuropsychological Assessment Laboratory, which meets INS/Division 40 guidelines for post-doctoral training in clinical neuropsychology. Responsibilities included comprehensive neuropsychological assessment and consultation services, including test administration, scoring, interpretation, and report writing. Regular outpatient psychotherapy was also provided for approximately two patients per week.
Patient Load: 4/week

1997-1999 Psychology, Neuropsychology, University of Pennsylvania Medical Center
Clinical Activity Description: Full-time two-year placement in the Department of Neurology, which meets INS/Division 40 guidelines for post-doctoral training in clinical neuropsychology. Responsibilities included neuropsychological assessment, consultation, and psychotherapy services for the Departments of Neurology and Neurosurgery.
Patient Load: 3/week

Report of Education of Patients and Service to the Community

Recognition

2003-2007 Who's Who in America, Marquis Who's Who
2004-2005 Who's Who in Medicine and Healthcare, Marquis Who's Who

Report of Scholarship

Publications

Peer reviewed publications in print or other media

A) Research Investigations:

1. **Killgore WD**. The Affect Grid: a moderately valid, nonspecific measure of pleasure and arousal. Psychol Rep. 83(2):639-42, 1998.

2. **Killgore WD**. Empirically derived factor indices for the Beck Depression Inventory. Psychol Rep. 84(3 Pt 1):1005-13, 1999.

3. **Killgore WD**. Affective valence and arousal in self-rated depression and anxiety. Percept Mot Skills. 89(1):301-4, 1999.

4. **Killgore WD**, Adams RL. Prediction of Boston Naming Test performance from vocabulary scores: preliminary guidelines for interpretation. Percept Mot Skills. 89(1):327-37, 1999.

5. **Killgore WD**, Gangestad SW. Sex differences in asymmetrically perceiving the intensity of facial expressions. Percept Mot Skills. 89(1):311-4, 1999.

6. **Killgore WD**. The visual analogue mood scale: can a single-item scale accurately classify depressive mood state? Psychol Rep. 85(3 Pt 2):1238-43, 1999.

7. **Killgore WD**, DellaPietra L, Casasanto DJ. Hemispheric laterality and self-rated personality traits. Percept Mot Skills. 89(3 Pt 1):994-6, 1999.

8. **Killgore WD**, Glosser G, Casasanto DJ, French JA, Alsop DC, Detre JA. Functional MRI and the Wada test provide complementary information for predicting post-operative seizure control. Seizure. 8(8):450-5, 1999.

9. **Killgore WD**. Evidence for a third factor on the Positive and Negative Affect Schedule in a college student sample. Percept Mot Skills. 90(1):147-52, 2000.

10. **Killgore WD**, Dellapietra L. Item response biases on the logical memory delayed recognition subtest of the Wechsler Memory Scale-III. Psychol Rep. 86(3 Pt 1):851-7, 2000.

11. **Killgore WD**, Casasanto DJ, Yurgelun-Todd DA, Maldjian JA, Detre JA. Functional activation of the left amygdala and hippocampus during associative encoding. Neuroreport. 11(10):2259-63, 2000.

12. Yurgelun-Todd DA, Gruber SA, Kanayama G, **Killgore WD**, Baird AA, Young AD. fMRI during affect discrimination in bipolar affective disorder. Bipolar Disord. 2(3 Pt 2):237-48, 2000.

13. **Killgore WD**. Sex differences in identifying the facial affect of normal and mirror-reversed faces. Percept Mot Skills. 91(2):525-30, 2000.

14. **Killgore WD**, DellaPietra L. Using the WMS-III to detect malingering: empirical validation of the rarely missed index (RMI). J Clin Exp Neuropsychol. 22(6):761-71, 2000.

15. Maldjian JA, Detre JA, **Killgore WD**, Judy K, Alsop D, Grossman M, Glosser G. Neuropsychologic performance after resection of an activation cluster involved in cognitive memory function. AJR Am J Roentgenol. 176(2):541-4, 2001.

16. **Killgore WD**, Oki M, Yurgelun-Todd DA. Sex-specific developmental changes in amygdala responses to affective faces. Neuroreport. 12(2):427-33, 2001.

17. **Killgore WD**, Yurgelun-Todd DA. Sex differences in amygdala activation during the perception of facial affect. Neuroreport. 12(11):2543-7, 2001.

18. Casasanto DJ, **Killgore WD**, Maldjian JA, Glosser G, Alsop DC, Cooke AM, Grossman M, Detre JA. Neural correlates of successful and unsuccessful verbal memory encoding. Brain Lang. 80(3):287-95, 2002.

19. **Killgore WD**. Laterality of lesions and trait-anxiety on working memory performance. Percept Mot Skills. 94(2):551-8, 2002.

20. **Killgore WD**, Cupp DW. Mood and sex of participant in perception of happy faces. Percept Mot Skills. 95(1):279-88, 2002.

21. Yurgelun-Todd DA, **Killgore WD**, Young AD. Sex differences in cerebral tissue volume and cognitive performance during adolescence. Psychol Rep. 91(3 Pt 1):743-57, 2002.

22. Yurgelun-Todd DA, **Killgore WD**, Cintron CB. Cognitive correlates of medial temporal lobe development across adolescence: a magnetic resonance imaging study. Percept Mot Skills. 96(1):3-17, 2003.

23. **Killgore WD**, Young AD, Femia LA, Bogorodzki P, Rogowska J, Yurgelun-Todd DA. Cortical and limbic activation during viewing of high- versus low-calorie foods. Neuroimage. 19(4):1381-94, 2003.

24. **Killgore WD**, Yurgelun-Todd DA. Activation of the amygdala and anterior cingulate during nonconscious processing of sad versus happy faces. Neuroimage. 21(4):1215-23, 2004.

25. **Killgore WD**, Yurgelun-Todd DA. Sex-related developmental differences in the lateralized activation of the prefrontal cortex and amygdala during perception of facial affect. Percept Mot Skills. 99(2):371-91, 2004.

26. **Killgore WD**, Glahn DC, Casasanto DJ. Development and Validation of the Design Organization Test (DOT): a rapid screening instrument for assessing visuospatial ability. J Clin Exp Neuropsychol. 27(4):449-59, 2005.

27. **Killgore WD**, Yurgelun-Todd DA. Body mass predicts orbitofrontal activity during visual presentations of high-calorie foods. Neuroreport. 16(8):859-63, 2005.

28. Wesensten NJ, **Killgore WD**, Balkin TJ. Performance and alertness effects of caffeine, dextroamphetamine, and modafinil during sleep deprivation. J Sleep Res. 14(3):255-66, 2005.

29. **Killgore WD**, Yurgelun-Todd DA. Social anxiety predicts amygdala activation in adolescents viewing fearful faces. Neuroreport. 16(15):1671-5, 2005.

30. **Killgore WD**, Yurgelun-Todd DA. Developmental changes in the functional brain responses of adolescents to images of high and low-calorie foods. Dev Psychobiol. 47(4):377-97, 2005.

31. Kahn-Greene ET, Lipizzi EL, Conrad AK, Kamimori GH, **Killgore WD**. Sleep deprivation adversely affects interpersonal responses to frustration. Pers Individ Dif. 41(8):1433-1443, 2006.

32. McBride SA, Balkin TJ, Kamimori GH, **Killgore WD**. Olfactory decrements as a function of two nights of sleep deprivation. J Sens Stud. 24(4):456-63, 2006.

33. **Killgore WD**, Yurgelun-Todd DA. Ventromedial prefrontal activity correlates with depressed mood in adolescent children. Neuroreport. 17(2):167-71, 2006.

34. **Killgore WD**, Vo AH, Castro CA, Hoge CW. Assessing risk propensity in American soldiers: preliminary reliability and validity of the Evaluation of Risks (EVAR) scale--English version. Mil Med. 171(3):233-9, 2006.

35. **Killgore WD**, Balkin TJ, Wesensten NJ. Impaired decision making following 49 h of sleep deprivation. J Sleep Res. 15(1):7-13, 2006.

36. **Killgore WD**, Stetz MC, Castro CA, Hoge CW. The effects of prior combat experience on the expression of somatic and affective symptoms in deploying soldiers. J Psychosom Res. 60(4):379-85, 2006.

37. **Killgore WD**, McBride SA, Killgore DB, Balkin TJ. The effects of caffeine, dextroamphetamine, and modafinil on humor appreciation during sleep deprivation. Sleep. 29(6):841-7, 2006.

38. **Killgore WD**, McBride SA. Odor identification accuracy declines following

24 h of sleep deprivation. J Sleep Res. 15(2):111-6, 2006.

39. **Killgore WD**, Yurgelun-Todd DA. Affect modulates appetite-related brain activity to images of food. Int J Eat Disord. 39(5):357-63, 2006.

40. Kendall AP, Kautz MA, Russo MB, **Killgore WD**. Effects of sleep deprivation on lateral visual attention. Int J Neurosci. 116(10):1125-38, 2006.

41. Yurgelun-Todd DA, **Killgore WD**. Fear-related activity in the prefrontal cortex increases with age during adolescence: a preliminary fMRI study. Neurosci Lett. 406(3):194-9, 2006.

42. **Killgore WD**, Killgore DB, Ganesan G, Krugler AL, Kamimori GH. Trait-anger enhances effects of caffeine on psychomotor vigilance performance. Percept Mot Skills. 103(3):883-6, 2006.

43. **Killgore WD**, Yurgelun-Todd DA. Unconscious processing of facial affect in children and adolescents. Soc Neurosci. 2(1):28-47, 2007.

44. **Killgore WD**, Yurgelun-Todd DA. The right-hemisphere and valence hypotheses: could they both be right (and sometimes left)?. Soc Cogn Affect Neurosci. 2(3):240-50, 2007.

45. **Killgore WD**, Killgore DB. Morningness-eveningness correlates with verbal ability in women but not men. Percept Mot Skills. 104(1):335-8, 2007.

46. **Killgore WD**, Killgore DB, Day LM, Li C, Kamimori GH, Balkin TJ. The effects of 53 hours of sleep deprivation on moral judgment. Sleep. 30(3):345-52, 2007.

47. Rosso IM, **Killgore WD**, Cintron CM, Gruber SA, Tohen M, Yurgelun-Todd DA. Reduced amygdala volumes in first-episode bipolar disorder and correlation with cerebral white matter. Biol Psychiatry. 61(6):743-9, 2007.

48. Kahn-Greene ET, Killgore DB, Kamimori GH, Balkin TJ, **Killgore WD**. The effects of sleep deprivation on symptoms of psychopathology in healthy adults. Sleep Med. 8(3):215-21, 2007.

49. **Killgore WD**. Effects of sleep deprivation and morningness-eveningness traits on risk-taking. Psychol Rep. 100(2):613-26, 2007.

50. **Killgore WD**, Gruber SA, Yurgelun-Todd DA. Depressed mood and lateralized prefrontal activity during a Stroop task in adolescent children. Neurosci Lett. 416(1):43-8, 2007.

51. **Killgore WD**, Yurgelun-Todd DA. Positive affect modulates activity in the

visual cortex to images of high calorie foods. Int J Neurosci. 117(5):643-53, 2007.

52. Vo AH, Satori R, Jabbari B, Green J, **Killgore WD**, Labutta R, Campbell WW. Botulinum toxin type-a in the prevention of migraine: a double-blind controlled trial. Aviat Space Environ Med. 78(5 Suppl):B113-8, 2007.

53. **Killgore WD**, Yurgelun-Todd DA. Neural correlates of emotional intelligence in adolescent children. Cogn Affect Behav Neurosci. 7(2):140-51, 2007.

54. **Killgore WD**, Kendall AP, Richards JM, McBride SA. Lack of degradation in visuospatial perception of line orientation after one night of sleep loss. Percept Mot Skills. 105(1):276-86, 2007.

55. **Killgore WD**, Lipizzi EL, Kamimori GH, Balkin TJ. Caffeine effects on risky decision making after 75 hours of sleep deprivation. Aviat Space Environ Med. 78(10):957-62, 2007.

56. **Killgore WD**, Richards JM, Killgore DB, Kamimori GH, Balkin TJ. The trait of Introversion-Extraversion predicts vulnerability to sleep deprivation. J Sleep Res. 16(4):354-63, 2007.

57. **Killgore WD**, Kahn-Green ET, Killgore DB, Kamimori GH, Balkin TJ. Effects of acute caffeine withdrawal on Short Category Test performance in sleep-deprived individuals. Percept Mot Skills. 105(3 pt.2):1265-74, 2007.

58. **Killgore WD**, Killgore DB, McBride SA, Kamimori GH, Balkin TJ. Odor identification ability predicts changes in symptoms of psychopathology following 56 hours of sleep deprivation. J Sensory Stud. 23(1):35-51, 2008.

59. **Killgore WD**, Rupp TL, Grugle NL, Reichardt RM, Lipizzi EL, Balkin TJ. Effects of dextroamphetamine, caffeine and modafinil on psychomotor vigilance test performance after 44 h of continuous wakefulness. J Sleep Res. 17(3):309-21, 2008.

60. Huck NO, McBride SA, Kendall AP, Grugle NL, **Killgore WD**. The effects of modafinil, caffeine, and dextroamphetamine on judgments of simple versus complex emotional expressions following sleep deprivation. Int. J Neuroscience. 118(4):487-502, 2008.

61. **Killgore WD**, Kahn-Greene ET, Lipizzi EL, Newman RA, Kamimori GH, Balkin TJ. Sleep deprivation reduces perceived emotional intelligence and constructive thinking skills. Sleep Med. 9(5):517-26, 2008

62. **Killgore WD**, Grugle NL, Killgore DB, Leavitt BP, Watlington GI, McNair S, Balkin TJ. Restoration of risk-propensity during sleep deprivation: caffeine,

dextroamphetamine, and modafinil. Aviat Space Environ Med. 79(9):867-74, 2008.

63. **Killgore WD**, Muckle AE, Grugle NL, Killgore DB, Balkin TJ. Sex differences in cognitive estimation during sleep deprivation: effects of stimulant countermeasures. Int J Neurosci. 118(11):1547-57, 2008.

64. **Killgore WD**, Cotting DI, Thomas JL, Cox AL, McGurk D, Vo AH, Castro CA, Hoge CW. Post-combat invincibility: violent combat experiences are associated with increased risk-taking propensity following deployment. J Psychiatr Res. 42(13):1112-21, 2008.

65. **Killgore WD**, Gruber SA, Yurgelun-Todd DA. Abnormal corticostriatal activity during fear perception in bipolar disorder. Neuroreport. 19(15):1523-7, 2008.

66. **Killgore WD**, McBride SA, Killgore DB, Balkin TJ, Kamimori GH. Baseline odor identification ability predicts degradation of psychomotor vigilance during 77 hours of sleep deprivation. Int. J Neurosci. 118(9):1207-1225, 2008.

67. **Killgore WD**, Rosso HM, Gruber SA, Yurgelun-Todd DA. Amygdala volume and verbal memory performance in schizophrenia and bipolar disorder. Cogn Behav Neur. 22(1):28-37, 2009.

68. **Killgore WD**, Kahn-Greene ET, Grugle NL, Killgore DB, Balkin TJ. Sustaining executive functions during sleep deprivation: A comparison of caffeine, dextroamphetamine, and modafinil. Sleep. 32(2):205-16, 2009.

69. **Killgore WD**, Grugle NL, Reichardt RM, Killgore DB, Balkin TJ. Executive functions and the ability to sustain vigilance during sleep loss. Aviat Space Environ Med. 80(2):81-7, 2009.

70. Picchioni, D, **Killgore, WD,** Braun, AR, & Balkin, TJ. Positron emission tomography correlates of EEG microarchitecture waveforms during non-REM sleep. Int J Neurosci. 119: 2074-2099, 2009.

71. **Killgore, WD**, Lipizzi, EL, Grugle, NL, Killgore, DB, & Balkin, TJ. Handedness correlates with actigraphically measured sleep in a controlled environment. Percept Mot Skills. 109: 395-400, 2009.

72. **Killgore, WD**, Killgore, DB, Grugle, NL, & Balkin, TJ. Odor identification predicts executive function deficits during sleep deprivation. Int J Neurosci, 120: 328-334, 2010.

73. **Killgore, WD**, Ross, AJ, Kamiya, T, Kawada, Y, Renshaw, PF, & Yurgelun-

Todd, DA. Citicoline affects appetite and cortico-limbic responses to images of high calorie foods. Int J Eat Disord. 43: 6-13, 2010.

74. **Killgore, WD,** & Yurgelun-Todd, DA. Cerebral correlates of amygdala responses during non-conscious perception of facial affect in adolescent and pre-adolescent children. Cogn Neurosci, 1: 33-43, 2010.

75. **Killgore, WD**, & Yurgelun-Todd, DA. Sex differences in cerebral responses to images of high vs low calorie food. Neuroreport, 21: 354-358, 2010.

76. **Killgore, WD**, Grugle, NL, Killgore, DB, & Balkin, TJ. Sex differences in self-reported risk-taking propensity on the Evaluation of Risks scale. Percept Mot Skills, 106: 693-700, 2010.

77. **Killgore, WD**, Kelley, AM, & Balkin, TJ. So you think you're bulletproof: Development and validation of the Invincibility Belief Index. Mil Med, 175: 499-508, 2010.

78. **Killgore, WD**, Castro, CA, & Hoge, CW. Preliminary Normative Data for the Evaluation of Risks Scale—Bubble Sheet Version (EVAR-B) for Large Scale Surveys of Returning Combat Veterans. Mil Med, 175: 725-731, 2010.

79. Britton, JC, Rauch, SL, Rosso, IM, **Killgore, WD**, Price, LM, Ragan, J, Chosak, A, Hezel, D, Pine, DS, Leibenluft, E, Pauls, DL, Jenike, MA, Stewart, SE. Cognitive inflexibility and frontal cortical activation in pediatric obsessive-compulsive disorder. J Am Acad Child Adolesc Psychiatry, 49: 944-953, 2010.

80. Britton, JC, Stewart, SE, **Killgore, WD**, Rosso, IM, Price, LM, Gold, AL, Pine, DS, Wilhelm, S, Jenike, MA, & Rauch, SL. Amygdala activation in response to facial expressions in pediatric obsessive-compulsive disorder. Depress Anxiety, 27: 643-651, 2010.

81. Rupp, TL, **Killgore, WD**, & Balkin, TJ. Socializing by day may affect performance by night: Vulnerability to sleep deprivation is differentially mediated by social exposure in extraverts vs. introverts. Sleep, 33: 1475-1485, 2010.

82. Rosso, IM, Makris, N, Britton, JC, Price, LM, Gold, AL, Zai, D, Bruyere, J, Deckersbach, T, **Killgore, WD**, & Rauch, SL. Anxiety sensitivity correlates with two indices of right anterior insula structure in specific animal phobia. Depress Anxiety, 27: 1104-1110, 2010.

83. **Killgore, WD**, Britton, JC, Price, LM, Gold, AL, Deckersbach, T, & Rauch, SL. Neural correlates of anxiety sensitivity during masked presentation of affective faces. Depress Anxiety, 28: 243-249, 2011.

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85. Capaldi, VF, Guerrero, ML, & **Killgore, WD**. Sleep disruption among returning combat veterans from Iraq and Afghanistan. Mil Med, 176: 879-888, 2011.

86. **Killgore, WD**, Grugle, NL, & Balkin, TJ. Gambling when sleep deprived: Don't bet on stimulants. Chronobiol Int, 29: 43-54, 2012

87. Gruber, SA, Kahlgren, MK, Sagar, KA, Gonenc, A, & **Killgore, WD.** Age of onset of marijuana use impacts inhibitory processing. Neurosci Lett 511(2):89-94, 2012.

88. **Killgore, WD**, Capaldi, VF, & Guerrero, ML. Nocturnal polysomnographic correlates of daytime sleepiness. Psychol Rep, 110(10), 63-72, 2012.

89. **Killgore, WD**, Weber, M, Schwab, ZJ, DelDonno, SR, Kipman, M, Weiner, MR, & Rauch, SL. Grey matter correlates of trait and ability models of emotional intelligence. Neuroreport 23, 551-555, 2012.

90. **Killgore, WD**, Schwab, ZJ, Kipman, M, DelDonno, SR, Weber, M. Voxel-based morphometric grey matter correlates of daytime sleepiness. Neurosci Lett, 518(1), 10-13, 2012.

91. **Killgore, WD**, Schwab, ZJ, & Weiner, MR. Self-reported nocturnal sleep duration is associated with next-day resting state functional connectivity. Neuroreport (in press).

92. **Killgore, WD**, & Schwab ZJ. Sex differences in the association between physical exercise and cognitive ability. Perceptual and Motor Skills (in press).

93. Kipman, M, Weber, M, Schwab, ZJ, DelDonno, SR, & **Killgore, WD**. A funny thing happened on the way to the scanner: Humor detection correlates with gray matter volume. Neuroreport (in press).

B) Other Peer Reviewed Publications

94. **Killgore WD**. Academic and research interest in several approaches to psychotherapy: a computerized search of literature in the past 16 years. Psychol Rep. 87(3 Pt 1):717-20, 2000.

Non-peer reviewed scientific or medical publications/materials in print or other media

Reviews/Chapters/Editorials

1. **Killgore, WD.** Cortical and limbic activation during visual perception of food. In Dube, L, Bechara, A, Dagher, A, Drewnowski, A, Lebel, J, James, P, & Yada, R. (Eds), Obesity Prevention: The Role of Brain and Society on Individual Behavior. Elsevier, Boston, 2010, pp. 57-71.

2. **Killgore, WD.** Asleep at the trigger: Warfighter judgment and decision-making during prolonged wakefulness. In Bartone, P. (Ed), Applying Research Psychology to Improve Performance and Policy. 2010, pp. 59-77.

3. **Killgore, WD.** Effects of Sleep Deprivation on Cognition. In Kerkhof, G. & Van Dongen, H. Progress in Brain Research: Sleep and Cognition. Elsevier, B.V. New York, 2010, pp. 105-129.

4. **Killgore, WD.** Caffeine and other alerting agents. In Thorpy, M. & Billiard, M. (Eds), Sleepiness: Causes, Consequences, Disorders and Treatment. Cambridge University Press, UK, 2011, pp. 430-443.

5. **Killgore WD.** Priorities and challenges for caffeine research: Energy drinks, PTSD, and withdrawal reversal. The Experts Speak Column, J Caffeine Res, 1, 11-12, 2011.

6. **Killgore, WD.** Odor identification ability predicts executive function deficits following sleep deprivation. In Lee-Chiong, T (Ed), Best of Sleep Medicine 2011. National Jewish Health, Denver CO, 2011, pp. 31-33.

7. **Killgore, WD.** Socio-emotional and neurocognitive effects of sleep loss. In Matthews, G. (Ed), Handbook of Operator Fatigue. Ashgate, London UK (in press)

8. **Killgore, WD**, & Penetar, DM. Sleep and Military Operational Effectiveness. In Kushida, CA (Ed), Encyclopedia of Sleep. Elsevier, Oxford UK. (in press)

9. **Killgore, WD**, Weiner, MR, & Schwab, ZJ. Sleep deprivation, personality, and psychopathic changes. In Kushida, CA (Ed), Encyclopedia of Sleep. Elsevier, Oxford UK. (in press)

10. Schoenberg, MR, & **Killgore, WD**. Psychologic and Psychiatric Assessment. In Kushida, CA (Ed), Encyclopedia of Sleep. Elsevier, Oxford UK. (in press)

11. **Killgore, WD.** Sleep loss and performance. In Moore, BA, & Barnett, JE (Eds), Military Psychologists' Desk Reference. Oxford University Press, New York. (in press)

12. **Killgore, WD.** Sleepless nights and bulging waistlines (Editorial). Journal of Sleep Disorders: Treatment and Care (in press)

13. **Killgore W.**D. & Weber, M. Sleep deprivation and cognitive performance. In Bianchi, M (Ed), Sleep Deprivation and Disease: Effects on the Body, Brain and Behavior. Springer, New York. (in press).

Published U.S. Government Technical Reports

1. **Killgore, WD**, Estrada, A, Rouse, T, Wildzunas, RM, Balkin, TJ. Sleep and performance measures in soldiers undergoing military relevant training. USAARL Report No. 2009-13. June, 2009.

2. Kelley, AM, **Killgore, WD**, Athy, JR, Dretsch, M. Risk propensity, risk perception, and sensation seeking in U.S. Army Soldiers: A preliminary study of a risk assessment battery.

USAARL Report No. 2010-02. DTIC #: ADA511524. October, 2009.

Professional educational materials or reports, in print or other media

1. **Killgore, WD,** & Bailey, JD. Sleep History And Readiness Predictor (SHARP). Silver Spring, MD: Walter Reed Army Institute of Research; 2006. Computer program for predicting cognitive status based on actigraphically recorded sleep history. Patent Pending.

Thesis

1. **Killgore, WD.** Senior Honors Thesis: Perceived intensity of lateral facial asymmetry of spontaneous vs. posed emotional expressions. Albuquerque, NM: University of New Mexico;1990. **(Outstanding Psychology Senior Honors Thesis, UNM-1990).*

2. **Killgore, WD.** Masters Thesis: Interaction of visual field and lateral facial asymmetry on the perceived intensity of emotional expressions in depressed and non-depressed subjects. Lubbock, TX: Texas Tech University;1992.

3. **Killgore, WD.** Dissertation: Development and validation of a new instrument for the measurement of transient mood states: The facial analogue mood scale (FAMS). Lubbock, TX: Texas Tech University;1995.

Abstracts, Poster Presentations and Exhibits Presented at Professional Meetings

1. **Killgore, WDS,** Stetz, MC, Castro, CA, & Hoge, CW. Somatic and emotional stress symptom expression prior to deployment by soldiers with and without previous combat experience [abstract]. Poster presented at the 6th Annual Force Health Protection Conference, Albuquerque, NM, August, 11-17, 2003. ***[*BEST PAPER AWARD]***

2. **Killgore, WD,** Britton, JC, Price, LM, Gold, AL, Deckersbach, T, & Rauch, SL. Small animal phobics show sustained amygdala activation in response to masked happy facial expressions. Abstract presented the 37th Annual Meeting of the International Neuropsychological Society, Atlanta, GA, February 11-14, 2009. ***[*MERIT POSTER AWARD]***

3. **Killgore, WD** & Yurgelun-Todd, DA. Cerebral correlates of amygdala responses during non-conscious perception of affective faces in adolescent children. Abstract presented at the 37th Annual Meeting of the International Neuropsychological Society, Atlanta, GA, February 11-14, 2009.

4. **Killgore, WD,** Killgore, DB, Grugle, NL, & Balkin, TJ. Odor identification ability predicts executive function deficits following sleep deprivation. Abstract presented the 37th Annual Meeting of the International Neuropsychological Society, Atlanta, GA, February 11-14, 2009.

5. **Killgore, WD,** Rupp, TL, Killgore, DB, Grugle, NL, and Balkin, TJ. Differential effects of stimulant medications on verbal and nonverbal fluency during sleep deprivation. Abstract presented the 37th Annual Meeting of the International Neuropsychological Society, Atlanta, GA, February 11-14, 2009.

6. **Killgore, WD,** Killgore, DB, Kamimori, GH, & Balkin, TJ. When being smart is a liability:

More intelligent individuals may be less resistant to sleep deprivation. Abstract presented the 37th Annual Meeting of the International Neuropsychological Society, Atlanta, GA, February 11-14, 2009.

7. **Killgore, WD,** Britton, JC, Price, LM, Gold, AL, Deckersbach, T, & Rauch, SL. Introversion is associated with greater amygdala and insula activation during viewing of masked affective stimuli. Abstract presented the 37th Annual Meeting of the International Neuropsychological Society, Atlanta, GA, February 11-14, 2009.

8. **Killgore, WD,** Britton, JC, Price, LM, Gold, AL, Deckersbach, T, & Rauch, SL. Amygdala responses of specific animal phobics do not differ from healthy controls during masked fearful face perception. Abstract presented the 37th Annual Meeting of the International Neuropsychological Society, Atlanta, GA, February 11-14, 2009.

9. Price, LM, **Killgore, WD,** Britton, JC, Kaufman, ML, Gold, AL, Deckersbach, T, & Rauch, SL. Anxiety sensitivity correlates with insula activation in response to masked fearful faces in specific animal phobics and healthy subjects. Abstract presented at the Annual Conference of the Anxiety Disorders Association of America, Santa Ana Pueblo, New Mexico, March 12-15, 2009.

10. **Killgore, WD,** Britton, JC, Price, LM, Gold, AL, Deckersbach, T, & Rauch, SL. Neuroticism is inversely correlated with amygdala and insula activation during masked presentations of affective stimuli. Abstract presented at the Annual Conference of the Anxiety Disorders Association of America, Santa Ana Pueblo, New Mexico, March 12-15, 2009.

11. **Killgore, WD,** Kelley, AM, & Balkin, TJ. Development and validation of a scale to measure the perception of invincibility. Abstract presented at the Annual Conference of the Anxiety Disorders Association of America, Santa Ana Pueblo, New Mexico, March 12-15, 2009.

12. Kelly, AM, **Killgore WD,** Athy, J, & Dretsch, M. Risk propensity, risk perception, risk aversion, and sensation seeking in U.S. Army soldiers. Abstract presented at the 80th Annual Scientific Meeting of the Aerospace Medical Association, Los Angeles, CA, May 3-7, 2009.

13. Britton, JC, Stewart, SE, Price, LM, **Killgore, WD,** Jenike, MA, & Rauch, SL. The neural correlates of negative priming in pediatric obsessive-compulsive disorder (OCD). Abstract presented at the 64th Annual Scientific Meeting of the Society of Biological Psychiatry, Vancouver, Canada, May 14-16, 2009.

14. **Killgore, WD,** Killgore, DB, Kamimori, GH, & Balkin, TJ. Caffeine protects against increased risk-taking behavior during severe sleep deprivation. Abstract presented at the 23rd Annual Meeting of the Associated Professional Sleep Societies, Seattle, Washington, June 7-12, 2009.

15. Killgore, DB, **Killgore, WD,** Grugle, NL, & Balkin, TJ. Executive functions predict the ability to sustain psychomotor vigilance during sleep loss. Abstract presented at the 23rd Annual Meeting of the Associated Professional Sleep Societies, Seattle, Washington, June 7-12, 2009.

16. **Killgore, WD,** & Yurgelun-Todd, DA. Trouble falling asleep is associated with reduced activation of dorsolateral prefrontal cortex during a simple attention task. Abstract presented at the 23rd Annual Meeting of the Associated Professional Sleep Societies, Seattle, Washington, June 7-12, 2009.

17. **Killgore, WD,** Kelley, AM, & Balkin, TJ. A new scale for measuring the perception of

invincibility. Abstract presented at the 12th Annual Force Health Protection Conference, Albuquerque, New Mexico, August 14-21, 2009.

18. **Killgore, WD,** Killgore, DB, Grugle, NL, & Balkin, TJ. Executive functions contribute to the ability to resist sleep loss. Abstract presented at the 12th Annual Force Health Protection Conference, Albuquerque, New Mexico, August 14-21, 2009.

19. **Killgore, WD,** Killgore, DB, Kamimori, GH, & Balkin, TJ. Caffeine reduces risk-taking behavior during severe sleep deprivation. Abstract presented at the 12th Annual Force Health Protection Conference, Albuquerque, New Mexico, August 14-21, 2009. ***[*WINNER BEST PAPER: RESEARCH]***

20. **Killgore, WD,** Castro, CA, & Hoge, CW. Normative data for the Evaluation of Risks Scale—Bubble Sheet Version (EVAR-B) for large scale surveys of returning combat veterans. Abstract presented at the 12th Annual Force Health Protection Conference, Albuquerque, New Mexico, August 14-21, 2009.

21. **Killgore, WD,** Castro, CA, & Hoge, CW. Combat exposure and post-deployment risky behavior. Abstract presented at the 12th Annual Force Health Protection Conference, Albuquerque, New Mexico, August 14-21, 2009.

22. **Killgore, WD**, Price, LM, Britton, JC, Simon, N, Pollack, MH, Weiner, MR, Schwab, ZJ, Rosso, IM, & Rauch, SL. Paralimbic responses to masked emotional faces in PTSD: Disorder and valence specificity. Abstract presented at the Annual McLean Hospital Research Day, January 29, 2010.

23. **Killgore, WD**, Killgore, DB, Kamimori, GH, & Balkin, TJ. Caffeine minimizes behavioral risk-taking during 75 hours of sleep deprivation. Abstract presented at the 38th Annual Meeting of the International Neuropsychological Society, Acapulco, Mexico, February 3-6, 2010.

24. **Killgore, WD** & Balkin, TJ. Vulnerability to sleep loss is affected by baseline executive function capacity. Abstract presented at the 38th Annual Meeting of the International Neuropsychological Society, Acapulco, Mexico, February 3-6, 2010.

25. **Killgore, WD**, Smith, KL, Reichardt, RM., Killgore, DB, & Balkin, TJ. Intellectual capacity is related to REM sleep following sleep deprivation. Abstract presented at the 38th Annual Meeting of the International Neuropsychological Society, Acapulco, Mexico, February 3-6, 2010.

26. **Killgore, WD** & Yurgelun-Todd, DA. Cerebral correlates of amygdala responses to masked fear, anger, and happiness in adolescent and pre-adolescent children. Abstract presented at the 38th Annual Meeting of the International Neuropsychological Society, Acapulco, Mexico, February 3-6, 2010.

27. **Killgore, WD**, Post, A, & Yurgelun-Todd, DA. Sex differences in cortico-limbic responses to images of high calorie food. Abstract presented at the 38th Annual Meeting of the International Neuropsychological Society, Acapulco, Mexico, February 3-6, 2010.

28. **Killgore, WD** & Yurgelun-Todd, DA. Self-reported insomnia is associated with increased activation within the default-mode network during a simple attention task. Abstract presented at the 38th Annual Meeting of the International Neuropsychological Society, Acapulco, Mexico, February 3-6, 2010.

29. **Killgore, WD**, Price, LM, Britton, JC, Gold, AL, Deckersbach, T, & Rauch, SL. Neural correlates of anxiety sensitivity factors during presentation of masked fearful faces. Abstract presented at the 38th Annual Meeting of the International Neuropsychological Society, Acapulco, Mexico, February 3-6, 2010.

30. **Killgore, WD**, Grugle, NL, Conrad, TA, & Balkin, TJ. Baseline executive function abilities predict risky behavior following sleep deprivation. Abstract presented at the 24th Annual Meeting of the Associated Professional Sleep Societies, San Antonio, Texas, June 5-9, 2010.

31. **Killgore, WD**, Grugle, NL, & Balkin, TJ. Judgment of objective vigilance performance is affected by sleep deprivation and stimulants. Abstract presented at the 24th Annual Meeting of the Associated Professional Sleep Societies, San Antonio, Texas, June 5-9, 2010.

32. Killgore, DB, **Killgore, WD**, Grugle, NL, & Balkin, TJ. Resistance to sleep loss and its relationship to decision making during sleep deprivation. Abstract presented at the 24th Annual Meeting of the Associated Professional Sleep Societies, San Antonio, Texas, June 5-9, 2010.

33. Killgore DB, **Killgore, WD**, Grugle, NL, & Balkin, TJ. Subjective sleepiness and objective performance: Differential effects of stimulants during sleep deprivation. Abstract presented at the 24th Annual Meeting of the Associated Professional Sleep Societies, San Antonio, Texas, June 5-9, 2010.

34. Rupp, TL, **Killgore, WD**, & Balkin, TJ. Vulnerability to sleep deprivation is differentially mediated by social exposure in extraverts vs. introverts. Oral presentation at the "Data Blitz" section at the 24th Annual Meeting of the Associated Professional Sleep Societies, San Antonio, Texas, June 5-9, 2010.

35. Rupp, TL, **Killgore, WD**, & Balkin, TJ. Extraverts may be more vulnerable than introverts to sleep deprivation on some measures of risk-taking and executive functioning. Abstract presented at the 24th Annual Meeting of the Associated Professional Sleep Societies, San Antonio, Texas, June 5-9, 2010.

36. Rupp, TL, **Killgore, WD**, & Balkin, TJ. Vulnerability to sleep deprivation is differentially mediated by social exposure in extraverts vs. introverts. Abstract presented at the 24th Annual Meeting of the Associated Professional Sleep Societies, San Antonio, Texas, June 5-9, 2010.

37. Capaldi, VF, Guerrero, ML, & **Killgore, WD**. Sleep disorders among OIF and OEF Soldiers. Abstract presented at the 24th Annual Meeting of the Associated Professional Sleep Societies, San Antonio, Texas, June 5-9, 2010.

38. **Killgore, WD**, Killgore, DB, Kamimori, GH, & Balkin, TJ. Caffeine reduces behavioral risk-taking during sleep deprivation. Abstract presented at the 65th Annual Meeting of the Society for Biological Psychiatry, New Orleans, Louisiana, May 20-22, 2010.

39. **Killgore, WD**, Price, LM, Britton, JC, Simon, N, Pollack, MH, Weiner, MR, Schwab, ZJ, Rosso, IM, & Rauch, SL. Paralimbic responses to masked emotional faces in PTSD: Disorder and valence specificity. Abstract presented at the 65th Annual Meeting of the Society for Biological Psychiatry, New Orleans, Louisiana, May 20-22, 2010.

40. Rosso, IM, Makris, N, Britton, JC, Price, LM, Gold, AL, Deckersbach, T, **Killgore, WD**, & Rauch SL. Anxiety sensitivity correlates with insular cortex volume and thickness in specific animal phobia. Abstract presented at the 65th Annual Meeting of the Society for Biological

Psychiatry, New Orleans, Louisiana, May 20-22, 2010.

41. Rupp, TL, **Killgore, WD**, & Balkin, TJ. Vulnerability to sleep deprivation is mediated by social exposure in extraverts versus introverts. Oral platform presentation at the 20th Congress of the European Sleep Research Society, Lisbon, Portugal, September 14-18, 2010.

42. **Killgore, WD**, Estrada, A, & Balkin, TJ. A tool for monitoring soldier fatigue and predicting cognitive readiness: The Sleep History and Readiness Predictor (SHARP). Abstract presented at the 27th Army Science Conference, Orlando, FL, November 29-December 2, 2010.

43. **Killgore, WD**, Kamimori, GH, & Balkin, TJ. Caffeinated gum minimizes risk-taking in soldiers during prolonged sleep deprivation. Abstract presented at the 27th Army Science Conference, Orlando, FL, November 29-December 2, 2010.

44. **Killgore, WD**, Britton, JC, Schwab, ZJ, Weiner, MR, Rosso, IM, & Rauch, SL. Exaggerated amygdala responses to masked fearful faces are specific to PTSD versus simple phobia. Oral platform presentation at the 27th Army Science Conference, Orlando, FL, November 29-December 2, 2010. ***[*WINNER BEST PAPER IN NEUROSCIENCE]***

45. **Killgore, WD**, Kamimori, GH, & Balkin, TJ. Sleep deprivation selectively impairs emotional aspects of cognitive functioning. Oral platform presentation at the 27th Army Science Conference, Orlando, FL, November 29-December 2, 2010.

46. Rupp, TL, **Killgore, WD**, & Balkin, TJ. Evaluation of personality and social exposure as individual difference factors influencing response to sleep deprivation. Oral platform presentation at the 27th Army Science Conference, Orlando, FL, November 29-December 2, 2010.

47. **Killgore, WD**, Britton, JC, Rosso, IM, Schwab, ZJ, Weiner, MR, & Rauch, SL. Shared and differential patterns of amygdalo-cortical activation across anxiety disorders. Abstract presented at the 49th Annual Meeting of the American College of Neuropsychopharmacology, Miami Beach, FL, December 5-9, 2010.

48. Rosso, IM, **Killgore, WD**, Britton, JC, Weiner, MR, Schwab, ZJ, & Rauch, SL. Neural correlates of PTSD symptom dimensions during emotional processing: A functional magnetic resonance imaging study. Abstract presented at the 49th Annual Meeting of the American College of Neuropsychopharmacology, Miami Beach, FL, December 5-9, 2010.

49. **Killgore, WD,** Rosso, IM, Britton, JC, Schwab, ZJ, Weiner, MR, & Rauch, SL. Cortico-limbic activation differentiates among anxiety disorders with and without a generalized threat response. Abstract presented at the McLean Hospital Research Day, January 13, 2011.

50. Weiner, MR, Schwab, ZJ, Rauch, SL, & **Killgore WD**. Personality factors predict brain responses to images of high-calorie foods. Abstract presented at the McLean Hospital Research Day, January 13, 2011.

51. Schwab, ZJ, Weiner, MR, Rauch, SL, & **Killgore, WD.** Emotional and cognitive intelligence: Support for the neural efficiency hypothesis. Abstract presented at the McLean Hospital Research Day, January 13, 2011.

52. Crowley, DJ, Covell, MJ, **Killgore, WD**, Schwab, ZJ, Weiner, MR, Acharya, D, Rosso, IM, & Silveri, MM. Differential influence of facial expression on inhibitory capacity in adolescents versus adults. Abstract presented at the McLean Hospital Research Day, January 13, 2011.

53. **Killgore, WD**, Britton, JC, Rosso, IM, Schwab, ZJ, Weiner, MR, & Rauch, SL. Similarities and differences in cortico-limbic responses to masked affect probes across anxiety disorders. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

54. Rosso, IM, **Killgore, WD**, Britton, JC, Weiner, MR, Schwab, ZJ, & Rauch, SL. Hyperarousal and reexperiencing symptoms of post-traumatic stress disorder are differentially associated with limbic-prefrontal brain responses to threatening stimuli. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

55. Schwab, ZJ, Weiner, MR, Rauch, SL, & **Killgore, WD**. Neural correlates of cognitive and emotional intelligence in adults. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

56. Schwab, ZJ, Weiner, MR, Rauch, SL, & **Killgore, WD**. Cognitive and emotional intelligences: Are they distinct or related constructs? Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

57. Schwab, ZJ, Weiner, MR, Rauch, SL, & **Killgore, WD**. Discrepancy scores between cognitive and emotional intelligence predict neural responses to affective stimuli. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

58. **Killgore, WD**, Schwab, ZJ, Weiner, MR, & Rauch, SL. Smart people go with their gut: Emotional intelligence correlates with non-conscious insular responses to facial trustworthiness. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

59. **Killgore, WD**, Weiner, MR, Schwab, ZJ, & Rauch, SL. Whom can you trust? Neural correlates of subliminal perception of facial trustworthiness. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

60. Weiner, MR, Schwab, ZJ, & Rauch, SL, **Killgore, WD**. Impulsiveness predicts responses of brain reward circuitry to high-calorie foods. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

61. Weiner, MR, Schwab, ZJ, & Rauch, SL, **Killgore, WD**. Conscientiousness predicts brain responses to images of high-calorie foods. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

62. Crowley, DJ, Covell, MJ, **Killgore, WD**, Schwab, ZJ, Weiner, MR, Acharya, D, Rosso, IM, & Silveri, MM. Differential influence of facial expression on inhibitory capacity in adolescents versus adults. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

63. Gruber, SA, Dahlgren, MK, **Killgore, WD**, Sagar, KA, & Racine, MT. Marijuana: Age of onset of use impacts executive function and brain activation. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

64. **Killgore, WD,** Conrad, TA, Grugle, NL, & Balkin, TJ. Baseline executive function abilities

correlate with risky behavior following sleep deprivation. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

65. **Killgore, WD,** Grugle, NL, Killgore, DB, & Balkin, TJ. Resistance to sleep loss and decision making during sleep deprivation. Abstract presented at the 39th Annual Meeting of the International Neuropsychological Society, Boston, MA, February 2-5, 2011.

66. **Killgore, WD,** Rosso, IM, Britton, JC, Schwab, ZJ, Weiner, MR, & Rauch, SL. Cortico-limbic activation differentiates among anxiety disorders with and without a generalized threat response. Abstract presented at the 66th Annual Meeting of the Society for Biological Psychiatry, San Francisco, CA, May 12-14, 2011. ***[*BLUE RIBBON FINALIST: CLINICAL/TRANSLATIONAL]***

67. Schwab, ZJ, Weiner, MR, Rauch, SL, & **Killgore, WD.** Emotional and cognitive intelligence: Support for the neural efficiency hypothesis. Abstract presented at the 66th Annual Meeting of the Society for Biological Psychiatry, San Francisco, CA, May 12-14, 2011.

68. Weiner, MR, Schwab, ZJ, Rauch, SL, & **Killgore WD**. Personality factors predict brain responses to images of high-calorie foods. Abstract presented at the 66th Annual Meeting of the Society for Biological Psychiatry, San Francisco, CA, May 12-14, 2011.

69. **Killgore, WD,** Grugle, NL, & Balkin, TJ. Sleep deprivation impairs recognition of specific emotions. Abstract presented at the 25th Annual Meeting of the Associated Professional Sleep Societies, Minneapolis, MN, June 11-15, 2011.

70. **Killgore, WD,** & Balkin, TJ. Does vulnerability to sleep deprivation influence the effectiveness of stimulants on psychomotor vigilance? Abstract presented at the 25th Annual Meeting of the Associated Professional Sleep Societies, Minneapolis, MN, June 11-15, 2011.

71. Killgore, DB, **Killgore, WD,** Grugle, NJ, & Balkin, TJ. Sleep deprivation impairs recognition of specific emotions. Abstract presented at the 25th Annual Meeting of the Associated Professional Sleep Societies, Minneapolis, MN, June 11-15, 2011.

72. Weiner, MR, Schwab, ZJ, & **Killgore, WD.** Daytime sleepiness is associated with altered brain activation during visual perception of high-calorie foods: An fMRI study. Abstract presented at the 25th Annual Meeting of the Associated Professional Sleep Societies, Minneapolis, MN, June 11-15, 2011.

73. Schwab, ZJ, Weiner, MR, & **Killgore, WD.** Functional MRI correlates of morningness-eveningness during visual presentation of high calorie foods. Abstract presented at the 25th Annual Meeting of the Associated Professional Sleep Societies, Minneapolis, MN, June 11-15, 2011.

74. **Killgore, WD,** Weiner, MR, & Schwab, ZJ. Daytime sleepiness affects prefrontal regulation of food intake. Abstract presented at the McLean Hospital Research Day, January 11, 2012.

75. Kipman, M, Schwab ZJ, Weiner, MR, DelDonno, S, Rauch SL, & **Killgore WD**. The insightful yet bitter comedian: The role of emotional versus cognitive intelligence in humor appreciation. Abstract presented at the McLean Hospital Research Day, January 11, 2012.

76. Weber, M, & **Killgore, WD**. Gray matter correlates of emotional intelligence. Abstract presented at the McLean Hospital Research Day, January 11, 2012.

77. Schwab, ZJ, & **Killgore, WD**. Sex differences in functional brain responses to food. Abstract presented at the McLean Hospital Research Day, January 11, 2012.

78. DelDonno, S, Schwab, ZJ, Kipman M, Rauch, SL, & **Killgore, WD**. The influence of cognitive and emotional intelligence on performance on the Iowa Gambling Task. Abstract presented at the McLean Hospital Research Day, January 11, 2012.

79. Song, CH, Kizielewicz, J, Schwab, ZJ, Weiner, MR, Rauch, SL, & **Killgore, WD**. Time is of the essence: The Design Organization Test as a valid, reliable, and brief measure of visuospatial ability. Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

80. Kipman, M, Schwab, ZJ, DelDonno, S, & **Killgore, WD**. Gender differences in the contribution of cognitive and emotional intelligence to the left visual field bias for facial perception. Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

81. Kipman, M., Schwab, ZJ, Weiner, MR, DelDonno, S, Rauch, SL, & **Killgore, WD**. Contributions of emotional versus cognitive intelligence in humor appreciation. Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

82. Schwab, ZJ, & **Killgore, WD**. Disentangling emotional and cognitive intelligence. Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

83. Schwab, ZJ, & **Killgore, WD**. Sex differences in functional brain responses to food. Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

84. DelDonno, S, Schwab, ZJ, Kipman, M, Rauch, SL, & **Killgore, WD**. The influence of cognitive and emotional intelligence on performance on the Iowa Gambling Task. Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

85. **Killgore, WD**, Britton, JC, Rosso, IM, Schwab, ZJ, Weiner, MR, & Rauch, SL. Shared and unique patterns of cortico-limbic activation across anxiety disorders. Oral paper presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

86. **Killgore, WD**, & Balkin, TJ. Sleep deprivation degrades recognition of specific emotions. Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

87. **Killgore, WD**, & Schwab, ZJ. Emotional intelligence correlates with somatic marker circuitry responses to subliminal cues of facial trustworthiness. Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

88. **Killgore, WD**, & Schwab, ZJ. Trust me! Neural correlates of the ability to identify facial trustworthiness. Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

89. **Killgore, WD**, Schwab, ZJ, Weiner, MR, Kipman, M, DelDonno, S, & Rauch SL. Overeating is associated with altered cortico-limbic responses to images of high calorie foods. Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

90. **Killgore, WD**, Weiner, MR, & Schwab, ZJ. Daytime sleepiness affects prefrontal regulation of food intake. Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

91. **Killgore, WD**. Overlapping and distinct patterns of neurocircuitry across PTSD, Panic Disorder, and Simple Phobia. Symposium presented at the 32nd Annual Conference of the Anxiety Disorders Association of America, Arlington, VA, April 12-15, 2012.

92. **Killgore, WD**, Britton, JC, Rosso, IM, Schwab, ZJ, & Rauch, SL. Shared and unique patterns of cortico-limbic activation across anxiety disorders. Abstract presented at the 67th Annual Meeting of the Society of Biological Psychiatry, Philadelphia, PA, May 3-5, 2012.

93. **Killgore, WD**, Schwab, ZJ, & Rauch, SL. Daytime sleepiness affects prefrontal inhibition of food consumption. Abstract presented at the 67th Annual Meeting of the Society of Biological Psychiatry, Philadelphia, PA, May 3-5, 2012.

94. Rosso, IM, Britton, JC, Makris, N, **Killgore, WDS**, Rauch SL, & Stewart ES. Impact of major depression comorbidity on prefrontal and anterior cingulate volumes in pediatric OCD. Abstract presented at the 67th Annual Meeting of the Society of Biological Psychiatry, Philadelphia, PA, May 3-5, 2012.

95. Kipman, M, Weber, M, DelDonno, S., Schwab, ZJ, & **Killgore, WD**. Morningness-Eveningness correlates with orbitofrontal gray matter volume. Abstract presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

96. Kipman, M, Schwab, ZJ, Weber, M, DelDonno, S, & **Killgore, WD**. Yawning frequency is correlated with reduced medial thalamic volume. Abstract presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

97. Weber, M, DelDonno, S, Kipman M, Schwab, ZJ, & **Killgore WD**. Grey matter correlates of daytime sleepiness. Abstract presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

98. Weber, M, DelDonno, S, Kipman M, Schwab, ZJ, & **Killgore WD**. Grey matter correlates of self-reported sleep duration. Abstract presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

99. DelDonno, S, Weber, M, Kipman M, Schwab, ZJ, & **Killgore, WD**. Resistance to insufficient sleep correlates with olfactory cortex gray matter. Abstract presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

100. DelDonno, S, Schwab, ZJ, Kipman, M, Weber, M, & **Killgore, WD**. Weekend sleep is related to greater coping and resilience capacities. Abstract presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

101. Schwab, ZJ, DelDonno, S, Weber, M, Kipman M, & **Killgore, WD**. Habitual caffeine consumption and cerebral gray matter volume. Abstract presented at the 26th Annual Meeting

of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

102. Schwab, ZJ, & **Killgore, WD**. Daytime sleepiness affects prefrontal regulation of food intake. Abstract presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

103. **Killgore, WD**, Schwab, ZJ, DelDonno S, Kipman, M, Weber M, & Rauch, SL. Greater nocturnal sleep time is associated with increased default mode functional connectivity. Abstract presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

104. **Killgore, WD**, Kamimori, GH, & Balkin, TJ. Caffeine improves efficiency of planning and sequencing abilities during sleep deprivation. Abstract presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

105. Sneider, JT, **Killgore, WD**, Crowley, DJ, Cohen-Gilbert, JE, Schwab, ZJ, & Silveri, MM. Inhibitory capacity in emerging adult binge drinkers: Influence of Facial Cues. Abstract presented at the 35th Annual Scientific Meeting of the Research Society on Alcoholism, San Francisco, CA, June 23-27, 2012.

106. Cohen-Gilbert, JE, **Killgore WD**, Crowley, DJ, Covell, MJ, Schwab, ZJ, Weiner, MR, Acharya, D, Sneider, JT, & Silveri, MM. Differential influence of safe versus threatening facial expressions on inhibitory control across adolescence and adulthood. Abstract submitted for presentation at the Society for Neuroscience 2012 Meeting, New Orleans, LA, October 13-17, 2012.

107. **Killgore WD**. Multimodal neuroimaging to predict cognitive resilience against sleep loss. Abstract presented at the DARPA Young Faculty Award 2012 Meeting, Arlington, VA, July 30-31, 2012.

Narrative Report (limit to 500 words)

My research has emphasized the study of higher order cognition and executive functions and how these cognitive abilities are influenced and guided by subtle affective processes. Over the past 12 years, my research has utilized functional and structural magnetic resonance imaging to study the interaction of affective processes and cognition within limbic networks of the medial temporal lobes and prefrontal cortex. This line of research has led to the refinement of a developmental model of prefrontal cortical-limbic maturation that explains how these processes contribute to the way adolescents perceive emotionally and motivationally relevant stimuli such as affective faces and visual images of food. As a result of the Iraq War, I took an extended leave of absence to serve in the Active Duty Army as the Chief of the Neurocognitive Performance Branch at the Walter Reed Army Institute of Research from 2002-2007. During that time, I extended the scope of my affective processing research to also examine the effects of stressors such as prolonged sleep deprivation, chronic sleep restriction, nutritional deprivation, and the use of stimulant countermeasures on the cognitive-affective systems within the brain. This line of investigation suggests that sleep deprivation alters the metabolic activity within the medial prefrontal cortex, resulting in subtle but profound effects on specific aspects of cognition. These sleep-loss related prefrontal decrements impair the ability to use affective processes to guide judgment and decision-making, particularly in high-risk or

morally relevant situations. My recent investigations also suggest that while commonly used stimulants such as caffeine, modafinil, and dextroamphetamine are highly effective at reversing sleep-loss induced deficits in alertness and vigilance, they have virtually no restorative effect on the cognitive-affective decision-making systems of the brain. Having left military service to return to McLean Hospital full time in the summer of 2007, I have since been extending my previous work to identify the extent to which these cognitive-affective decision-making systems and their neurobiological substrates are impaired or altered in patients suffering from anxiety disorders and post-traumatic stress. During the past three years I have also successfully secured three grants from the DoD totaling more than $2.8M, including a study of the neural basis of emotional intelligence, a study of a novel light treatment for improving sleep and cognitive functioning in mTBI, and a neuroimaging study of the effectiveness of an internet based cognitive-behavior therapy program. In early 2011, I was named Co-Director of the Social, Cognitive, and Affective Neuroscience Lab at McLean Hospital.

My recent teaching activities have primarily involved daily supervision and training of student research assistants and postdoctoral fellows, as well as occasional seminar presentations. Over the past 5 years, I have closely and regularly mentored more than 25 students at the undergraduate, graduate, and post-doctoral level. This involvement has included one-on-one supervision and training in basic research methods, neuropsychological assessment, statistical analysis, and manuscript preparation. Nearly all of my advisees have served as co-authors on abstracts, posters, talks, and published manuscripts based on my research program.

2012 Abstracts:

Grey Matter Correlates of Emotional Intelligence

Mareen Weber & William D.S. Killgore

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Recent theories of cognitive ability have emphasized the possibility of multiple intelligences that encompass a broader range of capacities than the traditional view of intellectual functioning. One such capacity, known as Emotional intelligence (EI), includes the ability to recognize, understand emotions in oneself and others, and to control and direct emotional processes adaptively to enhance decision-making. Damasio's influential Somatic Marker Hypothesis suggests an underlying neural network that is crucial to EI, including the amygdala, insula, and ventromedial prefrontal cortex. To evaluate the role of these structures in EI, we used voxel-based morphometry to examine the relationship between regional grey matter and standard measures of EI. We also examined two approaches to EI, including the Trait Model, which views EI as a stable trait similar to personality, and the Ability Model, which views EI as a set of capacities that are expressed through behavioral performance.

36 healthy participants completed the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT) and the Baron-On Emotional Quotient Inventory (EQ-i) followed by structural magnetic resonance imaging (MRI) at 3T. Using SPM8, brain tissue images were first normalized to standard stereotaxic space. Then, using an automated algorithm of the VBM8 toolbox, images were segmented into grey matter, white matter, and cerebrospinal fluid, and spatially smoothed. Scores on the MSCEIT and EQ-i were correlated with grey matter volume of the Somatic Marker circuitry, $p < .001$, uncorrected, with cluster extent established empirically as the statistically expected number of voxels per cluster in each analysis.

Measures of EI were significantly correlated with grey matter volume within several regions of the Somatic Marker circuitry. As hypothesized, total MSCEIT EI was positively correlated with grey matter volume in the left insula. When evaluated by subscale, the Strategic EI subscale correlated positively with right medial prefrontal cortex volume. In contrast, for the EQ-i, grey matter correlations were localized primarily within the ventromedial and orbitofrontal cortex regions, with findings particularly strong for the Stress Management subscale.

The findings link trait and ability measures of EI to grey matter volume, suggesting that these constructs are related to well defined neuroanatomical substrates. Notably, the ability and trait models of EI were differentially associated with grey matter volume in distinct brain regions. Whereas trait EI, which is measured through self-report, was associated primarily with greater volume of medial prefrontal cortex regions which are often associated with self-reflective thought and introspection, while the ability to use emotional information in decision-making was primarily associated with greater volume

of the insular cortex, a region involved in interoception and somatic-visceral sensations. These findings support the theoretical basis of the Somatic Marker circuitry in EI.

Abstract presented at the McLean Hospital Research Day, January 11, 2012.

The Insightful Yet Bitter Comedian: The role of Emotional versus Cognitive Intelligence in Humor Appreciation

Maia Kipman, Zachary J. Schwab, Melissa R. Weiner, Sophie DelDonno, Scott L. Rauch, & William D. S. Killgore

Social, Cognitive, & Affective Neuroscience Laboratory, McLean Hospital, Harvard Medical School

The ability to appreciate humor involves both cognitive and emotional processes. Prior research suggests that cognitive intelligence (IQ) is highly correlated with humor appreciation. We evaluated the individual and combined influences of IQ and emotional intelligence (EI) on performance on the Penn Humor Appreciation Test (HAT), a validated measure of the ability to appreciate subtle aspects of humor.

36 healthy adults (18 females) aged 18-45 completed the HAT, the Wechsler Abbreviated Scale of Intelligence (WASI) and two measures of EI; the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT) and the Bar-On Emotional Quotient Inventory (EQ-i).

In a hierarchical linear regression, verbal and performance IQ were entered at the first level, followed by stepwise entry of MSCEIT and EQ-i subscales to predict HAT scores. IQ variables accounted for a significant proportion of the variance in HAT (R^2=0.34, p=0.001). Above and beyond IQ, the MSCEIT Understanding Emotions factor (b=0.57) and EQ-i General Mood factor (b=-0.29) each accounted for additional variance (combined model R^2=0.55, p=0.04). In a subsequent analysis, all IQ and EI subscales were entered stepwise to predict HAT performance. In combination, only MSCEIT Understanding (b=0.80) and EQ-i General Mood (b=-0.28) survived tolerance thresholds (R^2=0.53, p<0.001).

Both emotional and cognitive intelligence are correlated with humor appreciation. Findings suggest, however, that the most important factors contributing to humor appreciation ability include strong capacities related to labeling and reasoning with emotions in conjunction with a more negative general mood. EI appears to provide better prediction of humor appreciation ability than traditional measures of IQ.

Abstract presented at the McLean Hospital Research Day, January 11, 2012.

Time is of the Essence: The Design Organization Test as a Valid, Reliable, & Brief Measure of Visuospatial Ability

Christina H. Song, Jill Kizielewicz, Zachary J. Schwab, Melissa R. Weiner, Scott L. Rauch, & William D. S. Killgore

Social, Cognitive, & Affective Neuroscience Laboratory

The Wechsler Scales are some of the most frequently used measures of intelligence. However, these scales are time consuming to administer, and there is a need for more time efficient measures that provide the same information. The Design Organization Test (DOT; Killgore et al., 2005) was developed as brief 2-minute alternative to the Wechsler Block Design (BD) subtest. The initial development study showed the DOT to be reliable and valid for assessing college students and clinical populations. The present study further examined the validity and reliability of the DOT in normal healthy adults.

36 healthy right-handed adults (13 male, 23 female) ranging in age from 18 to 45 completed the Wechsler Abbreviated Scale of Intelligence (WASI) and 2 alternative versions of the DOT. Test-retest reliability, alternate forms reliability, and concurrent validity were evaluated.

DOT scores correlated significantly with the WASI ($r=.73$, $p<.001$). Notably, Block Design (BD) scores were strongly correlated with the DOT, $r=.80$, $p<.001$. Alternate versions of the DOT were highly correlated with each other ($r=.82$, $p<.001$). Scores increased approximately 5 points between first ($M=36.03$, $SD=9.96$) and second ($M=41.00$, $SD=10.40$) administrations, $t(33) = -7.13$, $p<.05$, suggesting a small but reliable practice effect.

The DOT was found to be a valid measure of visuospatial ability that correlated highly with BD and total WASI scores. The DOT is recommended as an efficient alternative measure when the lengthy block design procedure is not practical.

Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

Emotional Intelligence Correlates with Somatic Marker Circuitry Responses to Subliminal Cues of Facial Trustworthiness

William D. S. Killgore & Zachary J. Schwab

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Emotional intelligence (EI) involves the ability to accurately perceive, understand, and use emotional information to improve cognition. The neural basis of EI has not been well delineated but may involve the Damasio somatic marker circuitry (medial prefrontal cortex [MPFC], insula, and amygdala). We tested the hypothesis that activation within this circuitry would be correlated with measured of EI during subliminal presentations of untrustworthy faces.

Forty-one healthy adults (22 male) ranging from 19 to 45 years of age completed the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT) and the Bar-On Emotional Quotient Inventory (EQi). Participants viewed faces varying in trustworthiness. Conscious awareness of trustworthy cues was minimized via rapid presentation of the target face (20 msec) and subsequent masking by a neutral expression (80 msec). Brain activation was correlated with EQi and MSCEIT. Three bilateral search territories comprising the somatic marker circuitry were interrogated ($p<.01$, $k\geq10$), including MPFC, insula, and amygdala.

Higher MSCEIT correlated with greater left insula and MPFC activation to low facial trustworthiness, but reduced activation of the rostral and middle cingulate gyrus and posterior orbitofrontal cortex. Higher EQi scores were associated with increased bilateral anterior insula responses and reduced amygdala responses to facial cues of untrustworthiness.

During subliminal perception of facial untrustworthiness, both measures of EI were associated with increased responsiveness of insular cortex, a region of the somatic marker circuitry posited to be critical for social emotions and interoceptive processing (i.e., "gut feelings"). Higher EI may involve increased interoceptive sensitivity to stimuli with high social relevance.

Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

Trust Me! Neural Correlates of the Ability to Identify Facial Trustworthiness

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The ability to identify trustworthy individuals is a critical aspect of human survival. Overt perception of untrustworthiness has been shown to activate the amygdala, but it is not clear how these patterns of activation relate to the actual ability to discriminate facial cues of trustworthiness.

Thirty-six healthy adults (20 male) ranging from 19 to 45 years of age underwent fMRI while viewing masked presentations of faces classified as either Trustworthy (T) or Untrustworthy. Conscious perception of trustworthiness cues was prevented via rapid presentation of the target face (20 msec), which was masked immediately by a neutral expression (N) mask (80 msec). Afterword, participants made overt trustworthiness judgments (OTJ) for 100 pairs of faces differing in qualities of trustworthiness. Contrast images comparing T and U fMRI conditions were regressed against OJT accuracy scores in SPM5. Whole brain analyses were evaluated at $p<.005$, $k\geq20$ voxels. A search territory within the amygdala was interrogated at $p<.01$, $k\geq5$ voxels.

OTJ accuracy ranged from 47% to 87%. During T>U contrasts, greater accuracy on the OTJ task correlated with increased activation within face processing regions of the fusiform and lingual gyri, and cerebellar vermis. During U>T contrasts, OTJ accuracy correlated with increased activation within affect processing regions such as the medial prefrontal cortex, insula, and hippocampus, and at a more liberal threshold, bilateral amygdala.

Individuals who were better at discriminating between overtly presented trustworthy and untrustworthy faces showed greater task-related activation of facial feature and affect processing systems during subliminal presentations of facial signals of trustworthiness.

Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

Overeating is Associated with Altered Cortico-Limbic Responses to Images of High Calorie Foods

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Developed countries are witnessing an alarming epidemic of obesity, yet the neurobiological underpinnings of excessive food intake remain poorly understood. Neuroimaging research has identified an important network of cortical and limbic regions that are activated by images of appetizing high calorie foods. Using whole brain functional magnetic resonance imaging (fMRI), we examined the correlation between self-reported difficulty modulating food intake and cortico-limbic responses to high-calorie food images. We hypothesized that the tendency to overeat would be associated with reduced activation of the prefrontal cortex, which is involved in behavioral inhibition, and increased responsiveness of limbic and paralimbic regions, which are involved in emotional and motivational processing.

During fMRI, 40 healthy adults (22 men) aged 18 to 45 viewed images of high- and low-calorie foods. Participants also completed several questions about dietary behavior. Contrast images comparing brain activation derived from the high- versus low-calorie conditions were correlated voxel-wise with responses to an excessive eating scale in a second-level regression model.

When viewing high- versus low-calorie foods, the tendency to eat more than intended was correlated with reduced activation within several regions of the dorsolateral prefrontal cortex bilaterally ($p<.001$), and increased activation of the right amygdala ($p<.005$).

When confronted with images of appetizing foods, self-reported difficulty regulating food intake was associated with reduced activation within regions of the brain purported to mediate behavioral control and increased activation of limbic regions involved in ascribing salience to motivationally relevant stimuli. Findings highlight a functional neurocircuitry that may be relevant to excessive food consumption.

Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

Daytime Sleepiness Affects Prefrontal Regulation of Food Intake

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Despite the alarming rate of obesity there has been minimal scientific progress in identifying and combating the causes of this epidemic. The prefrontal cortex is critical in the ability to modulate emotion and inhibit behavior. However, insufficient sleep is often associated with reduced metabolic activity within prefrontal regions. We tested whether daytime sleepiness would correlate with reduced prefrontal activation to appetizing high-calorie food images and whether this would predict difficulties modulating food intake.

Forty healthy adults (22 men) aged 18 to 45 underwent functional magnetic resonance imaging (fMRI) while viewing pictures of high- and low-calorie foods. Subjects completed the Epworth Sleepiness Scale (ESS) and provided a rating to the query "how often do you eat more than you intend to." In SPM5, contrast images comparing brain activation derived from the high- versus low-calorie conditions were correlated voxel-wise with scores from the ESS in a second-level regression model ($p<.001$, $k=10$).

Daytime sleepiness correlated with reduced activation in the ventromedial prefrontal cortex during perception of high- versus low-calorie food images ($r=-.54$, $p<.001$). Moreover, activation within this cluster was related to the tendency to eat more than intended, but only for women ($r=-.47$, $p=.048$).

For participants viewing enticing high-calorie food images, greater daytime sleepiness was associated with decreased activation in the prefrontal cortex, a region implicated in emotional and behavioral modulation. Activation of this region was directly correlated with overeating in women. Findings suggest that normal fluctuations in sleepiness may be sufficient to affect brain regions important for regulating food intake.

Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

Disentangling Emotional and Cognitive Intelligence

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Emotional intelligence (EI) has been described as the ability to perceive, understand, and use emotional information to facilitate thinking. While the construct of EI has garnered considerable lay attention over the past decade, there has been only modest scientific validation of the basis of this construct and whether it is indeed unique from traditional cognitive intelligence, as measured by the Wechsler scales (IQ). This issue has been clouded by contrary conceptualizations of EI as an "Ability" versus a "Trait" more akin to personality. To disentangle these constructs, we examined the inter-correlations among measures of EI, IQ, and personality.

Forty-one healthy adults (22 men) ranging from 18 to 45 completed the Bar-On EQ-I ("Trait" EI), Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT-"Ability" EI), Revised NEO Personality Inventory (NEO-PI-R), and the Verbal (VIQ), Performance (PIQ), and Full (FSIQ) scales of the Wechsler Abbreviated Scale of Intelligence (WASI). Data were analyzed with bivariate correlation and stepwise linear regression (alpha=.01).

MSCEIT and EQ-i were not significantly correlated (r=0.15). MSCEIT correlated with FSIQ (r=0.53), VIQ (r=0.53), and PIQ (r=0.43), but not personality. EQ-i was not correlated with IQ, but significantly correlated with Neuroticism (r=-0.65), Extraversion (r=0.49), and Conscientiousness (r=0.44). In regression analyses, EQ-i was predicted by a combination of Neuroticism, Conscientiousness, and Extraversion (R=0.83). MSCEIT was predicted by VIQ (R=0.53).

Ability and Trait measures of EI appear to be measuring different psychological constructs. Ability EI shares considerable variance with cognitive IQ (up to 28%), while Trait EI appears to be primarily a measure of personality.

Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

Daytime Sleepiness Affects Prefrontal Regulation of Food Intake

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Over the past few decades, there has been an unprecedented explosion in the rates of overweight and obesity, yet the neurobiological underpinnings of excessive food intake remain poorly understood. Notably, this epidemic corresponds closely with the decline in the average number of hours of sleep obtained each night. Because insufficient sleep has been linked to reduced metabolic activity within the prefrontal cortex and associated declines in inhibitory control, we hypothesized that daytime sleepiness would be related to reduced activation of the prefrontal cortex during perception of appetizing high-calorie foods and that this decline would be correlated with difficulties regulating food intake.

Forty healthy adults (22 men) aged 18 to 45 underwent functional magnetic resonance imaging (fMRI) while viewing photographs of high- and low-calorie foods in a blocked design. Subjects also completed the Epworth Sleepiness Scale (ESS) and provided a rating to the query "how often do you eat more than you intend to" on a scale ranging from 1 (never) to 10 (always). In SPM5, contrast images of the difference in brain activation derived from the high- versus low-calorie conditions were correlated voxel-wise with scores from the ESS in a second-level regression model ($p<.001$, $k=10$).

Daytime sleepiness correlated with reduced activation in the ventromedial prefrontal cortex during perception of high- versus low-calorie food images for the sample as a whole ($r=-.54$, $p<.001$). Moreover, activation within this cluster was related to the tendency to eat more than intended, but only for women ($r=-.47$, $p=.048$).

When presented with enticing high-calorie food images, greater daytime sleepiness was associated with decreased activation in the prefrontal cortex, a region implicated in emotional and behavioral control. Activation of this region was directly correlated with overeating in women but not men. Normal fluctuations in sleepiness may be sufficient to affect brain regions important for regulating food intake.

Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

The Influence of Cognitive and Emotional Intelligence on Performance on the Iowa Gambling Task

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Emotional Intelligence (EI), the ability to accurately perceive, understand, manage, and use emotional information to solve problems, is purported to be a capacity distinct from traditional cognitive intelligence. We sought to validate the EI construct by examining the contribution of EI to performance on the Iowa Gambling Task (IGT), a behavioral index of the ability to use emotional cues to guide advantageous decision-making.

Thirty-one healthy adults (16 females, ages 18-45) completed an "ability" test of EI (Mayer-Salovey-Caruso Emotional Intelligence Test; MSCEIT), a "trait" measure of EI (Bar-On Emotional Quotient Inventory; EQi), a measure of standard intelligence (Wechsler Abbreviated Scale of Intelligence; WASI), and the IGT. High and low EI groups were defined by a median split. Data were analyzed with repeated-measures ANCOVA.

For the MSCEIT, there was a main effect of EI group (p=.03), with high scorers showing better decision-making on the IGT than low scorers. However, this effect was no longer significant with IQ held constant (p=.11). Conversely, there was no main effect of EQi on IGT regardless of whether IQ was controlled (p=.62) or not (p=.82). Ability EI correlated significantly with performance on the last block of the IGT (r=.47), but this effect was lost after controlling for IQ.

Ability EI is a better predictor of performance on an emotional decision-making task than trait EI. However, the considerable shared variance between ability EI and standard intelligence appears to account for this effect. These findings raise doubts about the unique predictive validity of EI beyond standard cognitive intelligence.

Abstract presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

Sex Differences in Functional Brain Responses to Food

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There are significant sex differences in the rates of eating disorders, and emerging evidence suggests that men and women may show differential responses to food stimuli within brain regions that are critically involved in appetite regulation and eating behavior. Here, we examined sex differences in neural responses to images of foods.

Forty healthy adults (22 men) ranging in age from 18 to 45 underwent functional magnetic resonance imaging (fMRI) while viewing images of appetizing high-calorie and low-calorie foods. In SPM5, contrast images of brain activation (high-calorie foods > low-calorie foods) were created in a first level analysis and then compared between men and women in a two-sample t-test, while controlling for BMI ($p<.005$, $k\geq10$).

Men showed greater activation in response to high calorie foods than women in the anterior insular cortex (bilateral) and prefrontal cortex. Women showed greater activation in the right amygdala.

The brain responses of men and women to appetizing food imagery were significantly different in regions involved in gustatory and visceral responses (anterior insula), emotional salience (amygdala), and behavioral control (prefrontal cortex). Whereas women tended to activate a primary node in the emotional salience network when viewing enticing foods, men showed greater activation of inhibitory and visceral sensation regions, raising the possibility that observed sex differences in the prevalence of eating disorders may be related to differential activation of this neurocircuitry.

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Gender differences in the contribution of cognitive and emotional intelligence to the left visual field bias for facial perception

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Most right-handed individuals show a lateralized left visual field (LVF) bias in face processing, presumably due to right hemisphere dominance of this aspect of cognition. The magnitude of this bias is dependent on gender, as well as several cognitive and emotional characteristics. We examined the contributions of gender, cognitive intelligence (IQ), and emotional intelligence (EI) on the right hemisphere dominance for facial perception.

39 Healthy adults (21 males) aged 18-45 completed two Chimeric face tasks (Happy and Sad), measures of IQ (Wechsler Abbreviated Scale of Intelligence) and EI (Mayer-Salovey-Caruso Emotional Intelligence Test; MSCEIT & Bar-On Emotional Quotient Inventory; EQ-i).

Neither EI nor IQ predicts right hemisphere dominance in females. For males, IQ is correlated with greater LVF bias (Happy; r=0.320 p=0.047, Sad; r=0.402 p=0.011) while MSCEIT and EQ-i are not correlated. When IQ is controlled for, MSCEIT and EQ-i as full tests are not correlated with LVF bias in males. However, when EI is broken into subsets: MSCEIT Experiential strongly predicts less LVF bias when IQ is controlled for (Happy; r=-0.504 p=0.03, Sad; r=-0.491 p=0.03). A stepwise linear regression for sad faces in males accounts for 27% of the variance r=0.53 with IQ alone (b=0.569) and 45% of the variance r=0.67 when MSCEIT Experiential is added (b=-0.421). The effect of adding MSCEIT Experiential is significant at p=0.006.

This demonstrates that male LVF bias is predicted by cognitive intelligence, which increases the bias and experiential emotional intelligence, which decreases it. Strategic EI and EQ-i don't predict hemispheric dominance for face perception.

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Contributions of Emotional versus Cognitive Intelligence in Humor Appreciation

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The ability to appreciate humor involves both cognitive and emotional processes. Prior research suggests that cognitive intelligence (CI) is highly correlated with humor appreciation. We evaluated the individual and combined influences of CI and emotional intelligence (EI) on performance on the Penn Humor Appreciation Test (HAT), a validated measure of the ability to appreciate subtle aspects of humor.

36 healthy adults (18 females) aged 18-45 completed the HAT, the Wechsler Abbreviated Scale of Intelligence (WASI) and two measures of EI; the Meyer-Salovey-Caruso Emotional Intelligence Test (MSCEIT) and the Bar-On Emotional Quotient Inventory (EQ-i).

In a hierarchical linear regression, verbal and performance CI were entered at the first level, followed by stepwise entry of MSCEIT and EQ-i subscales to predict HAT scores. CI variables accounted for a significant proportion of the variance in HAT (R^2=0.34, p=0.001). Above and beyond IQ, the MSCEIT Understanding Emotions factor (b=0.57) and EQ-i General Mood factor (b=-0.29) each accounted for additional variance (combined model R^2=0.55, p=0.04). In a subsequent analysis, all CI and EI subscales were entered stepwise to predict HAT performance. In combination, only MSCEIT Understanding (b=0.80) and EQ-i General Mood (b=-0.28) contributed independent predictive variance (R^2=0.53, p<0.001).

Both emotional and cognitive intelligence are correlated with humor appreciation. Findings suggest, however, that the most important factors contributing to humor appreciation ability include strong capacities related to labeling and reasoning with emotions in conjunction with a more negative general trait mood. EI appears to provide better prediction of humor appreciation ability than traditional measures of CI.

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Yawning Frequency is Correlated with Reduced Medial Thalamic Volume

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Although yawning is a universal human experience, its purpose and neurobiological mechanisms remain poorly understood. Some evidence suggests that yawns may occur to reduce cerebral temperature, to increase oxygen intake, or to communicate empathy. Little structural neuroimaging evidence exists to link brain morphology to yawning, but some evidence suggests that patients with lesions to the center-median nucleus of the thalamus show an unusual tendency to yawn when hyperventilating. Here we used voxel-based morphometry (VBM) to explore the link between yawning tendency and gray matter volume.

Thirty-six healthy participants aged 18 to 45 (20 males) rated their normal frequency of yawning on a scale from 1 (never yawn) to 10 (always yawning) followed by structural magnetic resonance imaging (MRI) at 3T. Structural T1-weighted neuroimaging data were preprocessed using the VBM toolbox in SPM8, including DARTEL-normalization to MNI space, tissue segmentation, and spatially smoothing with an 8mm FWHM Gaussian kernel. Yawning frequency was then entered as a covariate of interest, with age and gender as nuisance covariates, and modulated gray matter volumes as the dependent variable. Data were evaluated at a threshold of $p<.001$, uncorrected, with an empirically defined extent threshold of $k>72$ voxels, based on the statistically expected number of voxels per cluster.

Yawning frequency was negatively correlated with a single cluster (99 voxels) gray matter in the right posterior dorsomedial thalamus. No other regions were positively or negatively correlated with yawning frequency.

Self-reported yawning frequency was associated with reduced gray matter volume within the posterior medial thalamus, even after controlling for age and sex. As yawning is a poorly understood phenomenon, these preliminary findings raise the possibility that yawning may be related to arousal systems mediated by the medial or central nuclei of the thalamus.

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Resistance to Insufficient Sleep Correlates with Olfactory Cortex Gray Matter

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Some evidence suggests that resistance to the cognitively degrading effects of sleep deprivation is partially related to prefrontal functioning and executive control. We have previously demonstrated that individuals with greater baseline olfactory identification capacities, a putative index of orbitofrontal cortex integrity, are better able to resist sleep deprivation up to three consecutive days when compared to individuals with poorer ability to discriminate and identify various smells. We hypothesized that individuals with greater self-reported resistance to sleep deprivation would have greater volume of the olfactory region of the orbitofrontal cortex using voxel-based morphometry (VBM).

Thirty-six healthy participants aged 18 to 45 (20 males) were queried about the threshold of sleep restriction that leads to a noticeable impairment in the ability to function at work (impairment threshold). Structural T1-weighted magnetic resonance images (MRI) were collected at 3T and analyzed using the SPM8 VBM toolbox. Images were DARTEL-normalized, segmented, and spatially smoothed (8mm FWHM). Impairment thresholds were correlated with gray matter volume in the olfactory cortex, using a small volume correction, $p<.05$, FWE for height and extent thresholds.

The self-reported impairment threshold ranged from 2 to 10 hours of minimal sleep necessary to avoid work impairments ($M=5.4$, $SD = 1.4$). As hypothesized, gray matter volume in the olfactory cortex was significantly negatively correlated with the impairment threshold, but this was only significant on the right side.

Larger gray matter volume in the right olfactory cortex, an area of the posterior orbitofrontal cortex, was associated with a greater self-reported ability to function effectively despite minimal amounts of sleep. Findings support the notion that prefrontal cortex integrity, including the olfactory cortex, confers some resistance to the degrading effects of sleep loss. Future research could examine the relationship between gray matter volume in this region and resistance to sleep loss under a controlled experimental environment.

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Weekend Sleep is Related to Greater Coping and Resilience Capacities

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Sleep deprivation has significant degrading effects on mood and emotional processes and has been linked to decreased behavioral coping abilities, increased risk-taking behavior, and increased scores on indices of some aspects of psychopathology. Notably, poor sleep is one of the most common symptoms reported among a diverse set of psychopathologies including PTSD, depression, and anxiety. Adequate sleep may play a protective role in preserving coping and resilience capacities. The present study investigated relationships between self-reported sleep quality during the workweek and on weekends and several facets of resilience.

Forty-four healthy individuals (ages 18-45, $M = 30.0$, $SD = 8.7$; 21 female) completed the Connor-Davidson Resilience Scale (CD-RISC), Invincibility Belief Index (IBI), NEO Personality Index Revised (NEO-PI-R), and a questionnaire asking about average sleep duration and sleep onset latency. Data were analyzed with Pearson's correlations.

Although average weekday sleep duration was unrelated to measures of resilience, weekend sleep duration was significantly correlated with higher scores on the CD-RISC and lower NEO Neuroticism ($p<.05$). Regarding the latency to fall asleep, individuals with shorter sleep onset latency on weekdays showed higher scores on the CD-RISC, global Invincibility, Audacity/Boldness/Courage, and lower Neuroticism ($p<.05$). Likewise, shorter sleep onset latency on weekends was related to higher CD-RISC, general invincibility, Audacity/Boldness/Courage, Adroitness/Cunning/Skill, and lower Neuroticism ($p<.05$).

Participants who reported obtaining more sleep and falling asleep more quickly, particularly on weekends reported greater resilience, boldness/courage, and lower neuroticism. Results suggest that emotional resilience may be mediated by the amount of sleep obtained on weekends and the latency to fall asleep. These findings suggest that "catching up" on sleep on weekends may actually have more beneficial effects on coping and resilience capacities than previously realized. Further research will be necessary to establish the causal direction of these relationships, however.

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Habitual Caffeine Consumption and Cerebral Gray Matter Volume

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Although caffeine is the most consumed stimulant in the world, little is known about its effects on brain structure. Some evidence suggests that caffeine may be protective against some types of dementia. One recent study reported that high or low levels of coffee consumption among women may be associated with larger hippocampal volume (Periaki et al., 2011). Here we examined the relationship between habitual caffeine intake and gray matter volume as measured by voxel-based morphometry (VBM).

Healthy participants (n=36), ranging in age from 18 to 45 (16 females) completed structural magnetic resonance imaging (MRI) at 3T. The T1-weighted scans were normalized to MNI space, tissue segmented, and spatially smoothed with an 8mm FWHM Gaussian kernel. Questionnaire information regarding habitual caffeine intake was transformed into estimated mg of caffeine based on data available from the website for the Center for Science in the Public Interest. Mean caffeine intake was entered as the covariate of interest, with age, gender, and weight as nuisance covariates and used to predict modulated gray matter volumes ($p<.005$, uncorrected, with an empirically defined extent threshold of $k>139$ voxels).

Caffeine intake was positively correlated with gray matter volume (1269 voxels) within the left medial temporal lobe, including the parahippocampal gyrus, hippocampus, amygdala, and fusiform gyrus. Caffeine intake was also associated with reduced gray matter volume in the superior medial prefrontal cortex (142 voxels).

Self-reported habitual caffeine consumption was associated with greater gray matter volume within medial temporal lobe structures critical for memory and emotional processing and reduced volume in a prefrontal region important for executive control and top down regulation of stress responses. Because of the bidirectional nature of the correlations, further research will be necessary to determine whether these differences in brain morphology cause increased consumption of caffeine, or whether the increased consumption produced the observed differences.

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Greater Nocturnal Sleep Time is Associated with Increased Default Mode Functional Connectivity

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Sleep deprivation is associated with reduced cerebral metabolic activity, particularly within medial regions of the brain commonly associated with the default mode network. Recent evidence suggests that sleep deprivation also reduces the functional connectivity between the medial prefrontal cortex and the amygdala during emotional processing, possibly explaining some of the mood and emotional changes often associated with sleep loss. Here we examine the correlation between cerebral functional connectivity and the amount of sleep obtained the night preceding the neuroimaging scan among healthy volunteers who slept at home according to their own schedules.

Thirty-nine healthy individuals (ages 18-45, *M* = 30.4, *SD* = 8.7; 21 female) completed a questionnaire asking about their recent sleep habits. Participants underwent resting state functional magnetic resonance imaging (fMRI) for 6 minutes at 3T. Data were preprocessed in SPM8, including slice-time correction, segmentation, realignment, normalization, and spatial smoothing (6mm FWHM). The Functional Connectivity Toolbox (CONN) was used to regress out tissue- and movement-related nuisance covariates and to calculate seed-to-voxel and region-of-interest (ROI) to ROI random effects connectivity analyses. Analyses were corrected for multiple comparisons, $p<.05$, FDR.

Self-reported at home sleep ranged from 5.5 to 9 hours (M=7.4, SD = 0.84). More sleep was associated with significantly enhanced functional connectivity between the medial prefrontal cortex and dorsal posterior cingulate cortex, retrospenial cingulate, amygdalo-hippocampal region, and dorsal prefrontal cortex. Sleep was associated with greater positive connectivity between the posterior cingulate region and anterior prefrontal cortex, anterior cingulate, and medial prefrontal region, and greater anticorrelation with associative visual cortex.

Participants who obtained more sleep at home the night preceding their scan showed significantly enhanced functional connectivity among a network of structures involved in self-reflection, emotional control, and memory processing. The effect of this enhanced functional connectivity on cognitive performance and mood remains to be explored.

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Morningness-Eveningness Correlates with Orbitofrontal Gray Matter Volume

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Individuals show considerable variability in preferences for diurnal activity and sleep. These preferences comprise a continuum of "morningness-eveningness," with morning chronotypes showing greater preference for activity in the morning hours and an earlier bedtime, while evening chronotypes show the opposite pattern. Despite the robustness of this phenomenon, little is known about the underlying neurobiological mechanisms that may contribute to these individual differences. Here we examined whether structural differences in prefrontal gray matter volume correlate with individual differences in circadian preferences.

36 healthy participants (20 males), ranging in age from 18-45, completed the Horne-Ostberg Morningness-Eveningness Questionnaire (MEQ) and underwent structural magnetic resonance imaging (MRI) at 3T. Using SPM8, brain tissue images were first normalized to standard stereotaxic space, segmented into grey matter, white matter, and cerebrospinal fluid, and spatially smoothed. Individual scores on the MEQ were correlated with gray matter volume of the orbitofrontal cortex after controlling for age and sex. This region was defined by the Wake Forest PickAtlas Toolbox for SPM.

MEQ scores ranged from 30 to 73 (M=50.4, SD=10.6). Greater eveningness (i.e., lower MEQ score) was significantly correlated with increased gray matter volume in the right lateral Orbitofrontal Cortex ($p<.001$, uncorrected; $k = 32$).

Individuals with stronger evening preferences tended to show increased gray matter volume in the Orbitofrontal cortex, a highly complex region of the brain that mediates complex executive functions such as set shifting and reward learning. Prior research has found that eveningness traits correlate with greater intelligence and verbal ability, but also with extraversion, impulsivity, and mood disturbance. The present findings suggest that some of these individual differences may be related to variability in prefrontal cortical structure and organization.

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Grey Matter Correlates of Daytime Sleepiness

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Sleep deprivation has been associated with reduced glucose metabolism within the prefrontal cortex in healthy individuals. Within many of these same regions of the prefrontal cortex, grey matter volume appears to be reduced among patients with narcolepsy, obstructive sleep apnea, and chronic insomnia. It is, therefore, possible that prefrontal grey matter volume may be affected by chronic sleep loss or, conversely, may contribute to symptoms of sleep disorders. There are currently no data on grey matter correlates of daytime sleepiness in healthy individuals. Using voxel-based morphometry (VBM), we investigated the association between self-reported daytime sleepiness and grey matter volume. Based on the findings from experimental sleep deprivation and clinical findings, we hypothesized that daytime sleepiness would be associated with reduced grey matter volume in the prefrontal cortex.

36 healthy participants aged 18 to 45 (mean age 30.0±8.9; 20 males) completed the Epworth Sleepiness Scale (ESS) followed by structural magnetic resonance imaging (MRI) at 3 T. Using an automated algorithm of the VBM8 toolbox in SPM8, T1-weighted structural images were first DARTEL-normalized to MNI space, segmented into grey matter, white matter and cerebrospinal fluid, and spatially smoothed with an 8mm FWHM Gaussian kernel. Modulated images were used to provide an estimate of voxelwise grey matter volume. Scores of the ESS were correlated with grey matter volume, $p<.001$, uncorrected, with a cluster threshold of 40 voxels. Gender and age served as covariates.

In line with our hypothesis, daytime sleepiness negatively correlated with grey matter volume in a cluster of 48 voxels within the left orbitofrontal cortex (MNI coordinates x=-9, y=27, z=-26).

This is the first VBM study to link self-reported daytime sleepiness with reduced grey matter volume in the orbitofrontal cortex. As the orbitofrontal cortex is involved in decision-making and emotion processing, future studies should also investigate neuropsychological performance in this context.

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Gray Matter Correlates of Self-Reported Sleep Duration

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While the National Sleep Foundation recommends that most healthy individuals should obtain between 7 to 8 hours of sleep per night, evidence suggests that most people do not routinely obtain the sleep they need. Furthermore, some people seem to need more sleep than others to maintain similar levels of daytime performance. It is currently not known how typical sleep duration is related to structural differences in brain morphology. Here we examined the correlation between self-reported average sleep duration and gray matter volume using voxel-based morphometry (VBM) in healthy individuals.

Thirty-six healthy participants aged 18 to 45 (20 males) completed a questionnaire about their sleep habits and then underwent structural magnetic resonance imaging (MRI) at 3T. Data were preprocessed using the SPM8 VBM toolbox. Structural T1-weighted images were DARTEL-normalized to MNI space, tissue segmented, and spatially smoothed with an 8mm FWHM Gaussian kernel. Modulated images were used to provide an estimate of voxelwise grey matter volume. Self-reported sleep during the week and during weekends were combined as a weighted average and entered as the covariate of interest to predict gray matter volume, while gender and age were entered as nuisance covariates. Data were evaluated at a threshold of $p<.001$, uncorrected, $k>100$ voxels.

Average nighttime sleep was positively correlated with gray matter volume in bilateral insular cortices (Left 121 voxels; MNI coordinates x=-45, y=-1, z=-6; Right 418 voxels; MNI coordinates x=33, y=-4, z=4). No regions were negatively correlated with average sleep.

Greater self-reported average nightly sleep was associated with greater gray matter volume in the insular cortex bilaterally. This region is associated with integration of somatosensory and visceral sensations with emotional and motivational processes. Because these data are correlational, further research will be necessary to determine whether sleep duration leads to gray matter changes or whether gray matter volume affects sleep duration.

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Differential influence of safe versus threatening facial expressions on inhibitory control across adolescence and adulthood

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Inhibitory control improves throughout adolescence and into adulthood, due largely to the maturation of prefrontal cortex (PFC). Connectivity between PFC and limbic circuits critical to emotional processing also develop during this time. Thus, the impact of emotional information on response inhibition may change over the course of development. In the present study, developmental differences in response inhibition were examined using a Go-NoGo task that required subjects to respond or inhibit responding based on threat or safety cues present in the expression of facial stimuli. The task included two conditions: one in which subjects were required to respond (Go) to safe faces while inhibiting responding (NoGo) to threatening faces, and a second in which subjects were asked to respond (Go) to threatening faces and inhibit responding (NoGo) to safe faces. Inhibitory control was measured as percent accuracy on NoGo trials in each condition. Eighty-seven subjects (44 female) between 12 and 45 years of age completed this task. Subjects were subdivided into three age groups: adolescent (12-14 years, N = 33), emerging adult (18-25 years, N = 25) and adult (25-45 years, N = 29). Results showed a significant main effect of age on NoGo accuracy across conditions. Significant improvements in response inhibition were seen between the adolescent and the two adult groups, but not between the two adult groups. When NoGo accuracy for threatening versus safe stimuli was compared in each age group, the two adult groups showed significantly fewer impulsive errors for safe versus threatening faces. This effect was not significant in the adolescent group. Given the rapid cognitive changes occurring in early adolescence, this group was further subdivided into 12-13 year-olds (N = 20) versus 14 year-olds (N = 13). Analyses of these two groups revealed a significant interaction between age and face type for NoGo accuracy. While the younger group showed no difference in performance based on facial expression, the older adolescents showed a significant advantage on 'safe' NoGo trials compared to 'threat' trials, as was seen in the adult groups. These findings suggest a developmental change, early in adolescence, in the influence of safe versus threatening facial expressions on inhibitory capacity. Further studies will be needed to differentiate the effects of developmental changes in speeded recognition versus emotional reactivity to safe and threatening facial cues.

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INHIBITORY CAPACITY IN EMERGING ADULT BINGE DRINKERS: INFLUENCE OF FACIAL CUES

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Binge alcohol consumption has been associated with alterations in cognitive functioning, behavioral self-control and the ability to ascribe emotional significance to stimuli. In the current study, response inhibition was examined in emerging adult binge alcohol drinkers and light alcohol drinkers, using two Go No Go (GNG) behavioral paradigms, one that required response inhibition to shapes and one that required response inhibition to threat or safety cues present in the expression of facial stimuli. Percent accuracy data for GNG trials were acquired from 8 binge drinkers (BD) aged 21.5 ± 1.1 years and 10 light drinkers (LD) aged 22.2 ± 1.5 years. For shapes GNG, although no group differences were observed, LD exhibited similar accuracy on Go and No Go trials, whereas BD performed worse on No Go trials than on Go trials ($p=.020$). For faces GNG, significantly better accuracy was observed on Go trials for safe faces than for threatening faces in both LD ($p=.016$) and BD ($p=.028$). For faces No Go trials, LD demonstrated better accuracy on threat ($p=.038$) and safe trials ($p=.009$) than BD, whereas BD performed worse on No Go Trials regardless of facial cue. BD displayed significantly faster reaction times on faces Go trials, regardless of facial cue ($p<.05$), but not on shapes Go trials. These findings suggest that binge alcohol consumption is associated with impaired inhibitory capacity particularly in the presence of facial cues of threat and safety. These data also indicate that while facial cues do not differentially influence the poor response inhibition observed in BD, the presence of a safe stimulus serves to enhance inhibitory capacity in LD. Thus, drinking pattern-related differences in the ability to discriminate and utilize social information may compromise inhibitory capacity in binge drinkers, which may in turn impair social decision-making.

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Gray matter correlates of Trait and Ability models of emotional intelligence

William D. S. Killgore, Mareen Weber, Zachary J. Schwab, Sophie R. DelDonno, Maia Kipman, Melissa R. Weiner and Scott L. Rauch

Research suggests that emotional intelligence capacities may be related to the functional integrity of the corticolimbic regions including the ventromedial prefrontal cortex, insula, and amygdala. No study has yet examined regional brain volumes in relation to the two dominant models of emotional intelligence: the Ability model, which posits a set of specific demonstrable capabilities for solving emotional problems, and the Trait model, which proposes a set of stable emotional competencies that can be assessed through subjectively rated self-report scales. In 36 healthy participants, we correlated scores on the Mayer–Salovey–Caruso Emotional Intelligence Test (an Ability measure) and the Bar-On Emotional Quotient Inventory (a Trait measure) with regional brain volumes using voxel-based morphometry. Total Mayer–Salovey–Caruso Emotional Intelligence Test scores were positively correlated with the left insula grey matter volume. The Strategic emotional intelligence subscale correlated positively with the left ventromedial prefrontal cortex and insular volume. In contrast, for the Bar-On Emotional Quotient Inventory, Stress Management scores correlated positively with the bilateral ventromedial prefrontal cortex volume. Amygdala volumes were unrelated to emotional intelligence measures. Findings support the role of the ventromedial prefrontal cortex and insula as key nodes in the emotional intelligence circuitry. *NeuroReport* 23:551–555 © 2012 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Introduction

Although some people cope skillfully with adversity and seem resilient in the face of challenging situations, others have greater difficulty managing their emotions and are prone to poor decision-making under stress. Together, these social, affective, and coping capacities have been described as emotional intelligence. The construct of emotional intelligence comprises a number of traits and competencies that involve attunement to multiple levels of emotional information and the ability to flexibly regulate and use emotions in an adaptive manner to facilitate effective judgment and decision-making, foster relationships, and achieve goals [1–3]. The exact nature of these capacities continues to be debated, with some researchers describing emotional intelligence in terms of trait-like competencies that can be measured through self-report (i.e. Trait models) [4], whereas others have argued that emotional intelligence is only validly conceptualized and measured in terms of demonstrable emotional reasoning abilities, more akin to traditional cognitive approaches to intelligence (i.e. Ability models) [2].

The integration of emotional information with other aspects of cognition appears to rely on the interaction of several key brain regions, particularly the medial orbitofrontal cortex, ventromedial prefrontal cortex, insular cortex, and amygdala [5]. Together, these constitute the Somatic Marker Circuitry [5], which is hypothesized to integrate emotional states, previous learning, and conscious cognition to guide decision-making toward advantageous outcomes [6]. The ventromedial prefrontal cortex appears to be particularly crucial, given its roles in emotional regulation [7], judgment, and advantageous decision-making [8]. The insular cortex is important for processing the interoceptive cues involved in emotion [9,10], and integrating them with ongoing cognition [11]. Despite the burgeoning literature on various social, cognitive, and interpersonal aspects of emotional intelligence and social cognition, there is only limited research into the neurobiological basis of emotional intelligence. Functional neuroimaging has supported the role of the medial prefrontal cortex in emotional intelligence [12,13], and two published studies have examined the correlation between self-reported perceptions of emotional intelligence traits with voxel-wise gray matter volume in the brain [14,15]. Although both studies implicated gray matter volume in the ventromedial prefrontal cortex, the two studies were discordant in the direction of the reported association, and both used only self-report trait measures of emotional intelligence. To our knowledge, no study has yet examined the relationship between brain structure and ability-based measures of emotional intelligence. In the present study, we used voxel-based morphometry to evaluate the relationship between gray matter volume of the Somatic Marker Circuitry and emotional intelligence as measured by

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both the Trait and Ability models. We hypothesized that higher emotional intelligence as assessed by both models, particularly regarding facets involving emotional control, would be associated with greater gray matter volume of the ventromedial prefrontal cortex, insula, and amygdala, as key regions of the Somatic Marker Circuitry.

Methods

Participants

Thirty-six right-handed, primary English-speaking adults (mean age 30.0 ± 8.9, range 18–45; 20 men) were recruited from the Boston metropolitan area and received payment for their time. Participants had no history of neurological, psychiatric, or substance use disorders (including alcohol and illicit drugs). This research was approved by the McLean Hospital Institutional Review Board. All participants provided written informed consent.

Materials and procedure

Each participant completed two validated and commercially available tests that measure alternative models of emotional intelligence. The Ability model defines emotional intelligence in terms of measurable capacities to reason about and solve emotional problems in a manner similar to traditional intelligence tests [2]. This can be contrasted with Trait (or Mixed) models of emotional intelligence, which view these capacities more loosely as personal competencies that reflect an individual's potential to cope with environmental demands [4], and which can be assessed by self-report inventories rather than through objective problem solving tests. As an index of Ability emotional intelligence, participants completed the Mayer–Salovey–Caruso Emotional Intelligence Test (MSCEIT) [2]. The MSCEIT uses 141 computer-administered items to measure the ability to identify emotions, to understand what causes different emotions, and to utilize emotions to facilitate behavior and achieve goals. Participants rate various stimuli such as abstract pictures, music, and faces on several emotional dimensions, and answer questions about how various moods and emotions affect thinking. Other items ask questions about how various emotions blend together or how one emotion (e.g. anger) can transition into another (e.g. rage). Participants also rate various strategies for regulating emotions in different situations and the effectiveness of such strategies for achieving goals. The MSCEIT yields a Total emotional intelligence score and two Area scores, Experiential emotional intelligence and Strategic emotional intelligence. Experiential emotional intelligence reflects the ability to perceive emotions in oneself, other persons, and various inanimate stimuli, and to utilize emotional information in facilitating cognition. Strategic emotional intelligence reflects the ability to understand emotions and their evolution in oneself and others, and to manage them in an efficient and effective manner. Raw scores were converted to scaled scores on the basis of the general normative group, without adjustment for sex.

As a measure of Trait emotional intelligence, participants completed the Bar-On Emotional Quotient Inventory (EQ-i) [4]. This 125-item self-report inventory yields a Total Emotional Quotient and five composite scores (i.e. Interpersonal, Intrapersonal, Adaptability, Stress Management, General Mood). The inventory includes items such as 'I'm aware of the way I feel' and 'I don't hold up well under stress', which must be answered on a five-point Likert scale ranging from 'Very Seldom or Not True of Me' to 'Very Often True of Me or True of Me.' The Interpersonal scale provides a measure of perceived empathy and interpersonal skills, whereas the Intrapersonal scale reflects self-perceived awareness of one's own emotions and self-regard. The Adaptability scale reflects the perceived ability to objectively analyze problematic situations, to solve them, and to adapt to changing environments. Stress Management reflects tolerance of and perceived self-control during stressful or demanding situations. The General Mood scale reflects self-reported positive thinking and overall contentedness with personal life.

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Statistical analysis

Normalized smoothed gray matter images were entered into a series of random effects multiple regression analyses in SPM8. We conducted a search territory region-of-interest analysis of the Somatic Marker Circuitry (i.e. bilateral insula, amygdala, ventromedial prefrontal cortex) using an anatomical mask on the basis of the Automated Anatomical Labeling Atlas [16], as implemented in the Wake Forest University PickAtlas Utility for SPM [17]. Within the region of interest, separate regression analyses were used to predict gray matter volume from MSCEIT and EQ-i total and subscale scores. All analyses used an

uncorrected height threshold ($P < 0.001$) and an extent threshold established empirically as the statistically expected number of voxels per cluster in each analysis (i.e. 79) according to the SPM8 output. Age and sex served as nuisance covariates in all analyses.

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Table 1 Mean, SD and range of Ability and Trait measures of Emotional Intelligence

EI measure	Mean±SD	Range
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EI, Emotional Intelligence; EQ, Emotional Quotient; EQ-i, Bar-On Emotional Quotient Inventory; MSCEIT, Mayer-Salovey-Caruso Emotional Intelligence Test.

Discussion

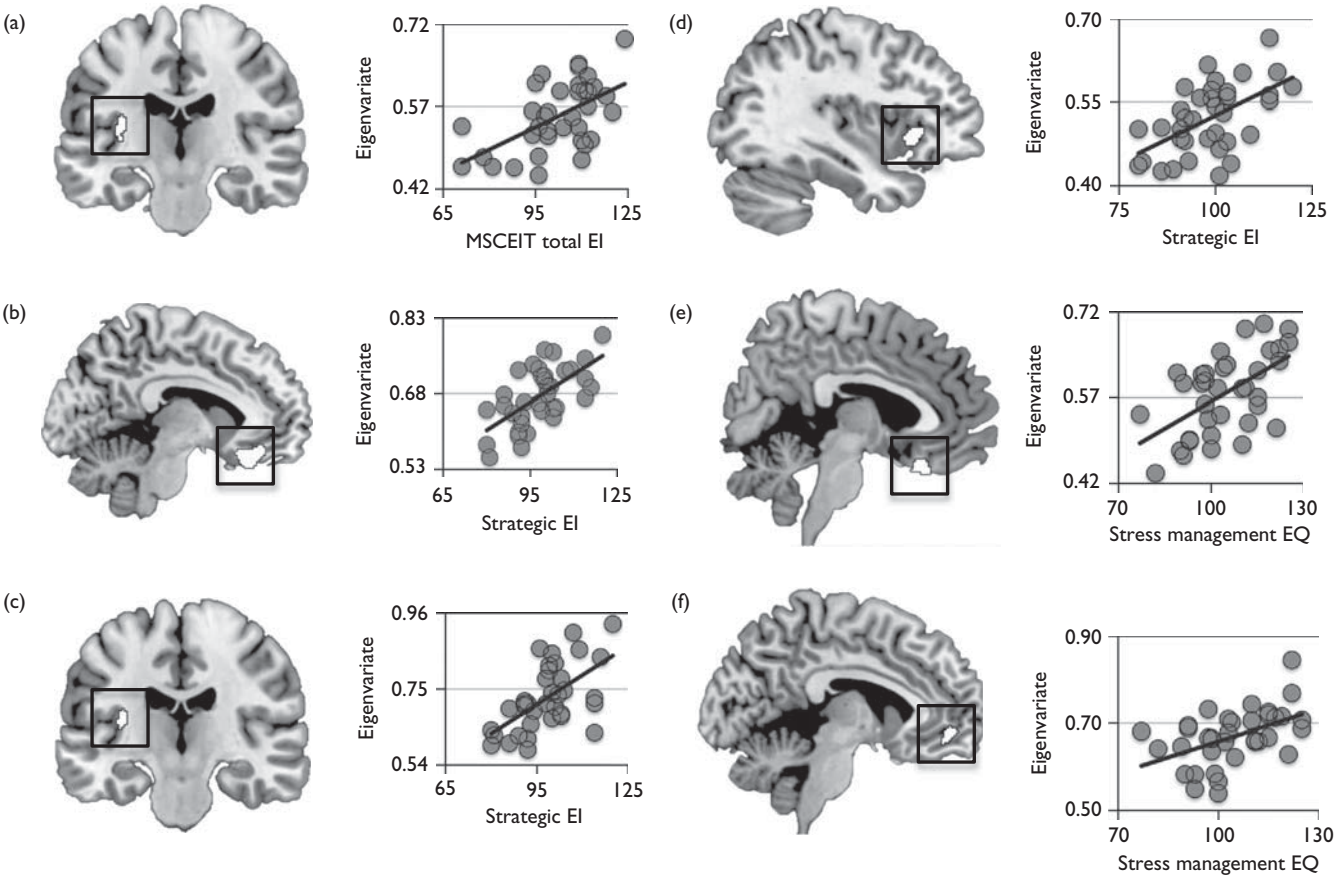
Specific facets of the Ability and Trait models of emotional intelligence correlated positively with gray matter volume in regions of the Somatic Marker Circuitry. Total scores on the MSCEIT, an Ability measure of emotional intelligence, correlated positively with gray matter volume within the left posterior insula, a region implicated in somatic [9] and emotional processing [18], and which may be particularly activated by focused attention toward one's own emotional state [19]. As an Ability measure, the MSCEIT assesses emotional intelligence in terms of measurable performance capacities involved in reasoning about and solving emotional problems, which are divided into two broad areas or domains of functioning. Of the two MSCEIT Area scores, Experiential and Strategic emotional intelligence, only Strategic emotional intelligence was significantly related to gray matter volume in the Somatic Marker Circuitry regions. Strategic emotional intelligence, which involves the ability to understand the meaning of emotional information (e.g. understanding how various emotions are related and what factors affect emotional change) and the ability to regulate emotions in oneself and others (e.g. modulating emotional states to achieve particular goals) [2], was associated with greater gray matter volume in the ventromedial prefrontal cortex, anterior insula, and posterior insula. This is consistent with previous findings suggesting that the ventromedial prefrontal cortex is important for emotional control [7,20], and evidence suggesting that damage to this region may lead to deficits in regulating emotion, poor judgment, and impaired decision-making [8]. Recent functional neuroimaging findings suggest that the ventromedial prefrontal cortex plays a prominent role in resilience against stress and trauma [21], whereas morphometric findings have shown that coping with stress early in life is associated with expansion of ventromedial prefrontal cortex volume in nonhuman primates [22]. Experiential emotional intelligence, which involves perceptual awareness of emotional signals and the ability to use emotions to facilitate thought [2], was unrelated to gray matter volume

Table 2 Gray matter correlates of Emotional Intelligence

			MNI coordinates				
EI measure	Region	Cluster size	*x*	*y*	*z*	*T*	*r*
MSCEIT (Ability Emotional Intelligence)							
Total EI	Posterior insula	159	−32	−19	12	4.66	0.56
Strategic EI	VMPFC	584	−4	39	−15	4.69	0.63
		123	10	58	−14	4.47	0.56
	Posterior insula	111	−32	−19	13	4.38	0.56
	Anterior insula/ventrolateral PFC	225	−38	21	−2	4.31	0.60
EQ-I (Trait Emotional Intelligence)							
Stress Management EQ	VMPFC	185	4	24	−24	4.47	0.56
		110	−8	51	−8	3.73	0.48

EI, Emotional Intelligence; EQ, Emotional Quotient; EQ-i, Bar-On Emotional Quotient Inventory; MNI, Montreal Neurological Institute; MSCEIT, Mayer-Salovey-Caruso Emotional Intelligence Test; PFC, prefrontal cortex; VMPFC, ventromedial prefrontal cortex.

Fig. 1



Brain regions with significant positive correlations between gray matter volume and Emotional Intelligence measures superimposed on a single-subject T1-weighted structural image and corresponding scatterplots. (a) Coronal view of the left posterior insula gray matter volume that correlated with the total MSCEIT emotional intelligence. (b) Sagittal view of the left ventromedial prefrontal cortex (gyrus rectus and medial frontal gyrus, orbital region) gray matter volume that correlated with Strategic emotional intelligence. (c) Coronal view of the left posterior insula gray matter volume that correlated with Strategic emotional intelligence. (d) Sagittal view of the left anterior insula/ventrolateral (inferior frontal gyrus) prefrontal cortex gray matter volume that correlated with Strategic emotional intelligence. (e) Coronal view of the right ventromedial prefrontal cortex (gyrus rectus) gray matter volume that correlated with Stress Management EQ. (f) Sagittal view of the left ventromedial prefrontal cortex (medial frontal gyrus, orbital region) gray matter volume that correlated with Stress Management EQ. EI, Emotional Intelligence; EQ, Emotional Quotient; MSCEIT, Mayer-Salovey-Caruso Emotional Intelligence Test.

in any of the hypothesized regions. This suggests that while the volume of structures within the hypothesized neurocircuitry was associated with reasoning about emotions, it was not related to perception of emotional information or using emotions to facilitate thought. Notably, while the amygdala has also been implicated as an important node of the Somatic Marker Circuitry, volumetric measures of this structure were not significantly related to Ability emotional intelligence measures.

We also examined gray matter volume correlates of Trait emotional intelligence on the EQ-i. Total EQ-i and four of its five subscale scores, including the Interpersonal, Intrapersonal, Adaptability, and General Mood scores, were not significantly correlated with gray matter volume in the hypothesized regions. Higher scores on the Stress Management subscale were, however, significantly correlated with greater gray matter volume within the bilateral ventromedial prefrontal cortex. Persons with high Stress Management scores are reported to cope with stress in an active and resourceful manner while maintaining a positive, composed, and self-confident outlook [4]. This ability to maintain emotional control and demonstrate positive coping and resilience in the face of adversity was reported to a greater degree among those with elevated gray matter volume of ventromedial prefrontal cortex regions, which have previously been implicated in emotional control [7,20,23]. As with the Ability measure of emotional intelligence, amygdala volume was not significantly correlated with Trait emotional intelligence scores.

To our knowledge, this is the first study to examine the brain morphometric correlates of the two dominant models of emotional intelligence by employing widely used, standardized, well-validated, and commercially available assessment instruments. Findings converge on the key

role of the ventromedial prefrontal cortex in emotional intelligence, as gray matter volume in this region was positively correlated with facets of emotional intelligence related to emotional control, regardless of whether assessed via the Trait or Ability models. Higher gray matter volume in ventromedial prefrontal cortex was associated with demonstrated ability to understand and manage emotional information (i.e. MSCEIT Strategic emotional intelligence) and self-reported traits suggestive of the ability to cope with adversity without losing emotional control (i.e. EQ-i Stress Management). A previous study also showed that gray matter volume in this same region was associated with one facet of perceived emotional intelligence that involves directing attention toward conscious subjective emotional experience [15]. Previous work has also suggested that higher Trait emotional intelligence is associated with reduced ventromedial prefrontal cortex and frontal pole activation [12,13], suggesting greater neural efficiency within these prefrontal regions among individuals with higher emotional functioning. The present findings also support the role of the insular cortex in emotional intelligence. We found that greater gray matter volume in the posterior insula, a region important for interoceptive perception [9], and in the anterior insula, a region that is critical for integration of cognition and emotion [11], was associated with higher Total and Strategic emotional intelligence scores. In contrast to the significant correlations between emotional intelligence and gray matter volume in the ventromedial prefrontal cortex and insula, there was no relationship with amygdala volumes. Although the amygdala is part of the Somatic Marker Circuitry, previous morphometric work has also failed to demonstrate volumetric relations between the amygdala and emotional intelligence [14,15]. This may be a consequence of the fact that the amygdala comprises several functionally distinct nuclei, each of relatively small volume compared with the spatial resolution of modern voxel-based morphometry methods, such as those used here. Future work may examine these emotional intelligence measures in groups with various forms of psychopathology, or even study the potential of emotional intelligence to predict resilience against stress or psychiatric disease.

Conclusion

Trait and Ability measures involving emotional regulation facets of emotional intelligence were both related to gray matter volume in the ventromedial prefrontal cortex, whereas only Ability emotional intelligence was specifically associated with gray matter volume in the insular cortex. These findings support the role of the ventromedial prefrontal cortex and insula as key nodes in the Somatic Marker Circuitry, and further suggest that larger volume of these regions in nominally healthy adult participants is associated with greater capacities for understanding and using emotional information and for demonstrating resilience and effective coping in the face of stress and adversity.

Acknowledgements

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Conflicts of interest

There are no conflicts of interest.

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Gray matter correlates of Trait and Ability models of emotional intelligence

William D. S. Killgore, Mareen Weber, Zachary J. Schwab, Sophie R. DelDonno, Maia Kipman, Melissa R. Weiner and Scott L. Rauch

Research suggests that emotional intelligence capacities may be related to the functional integrity of the corticolimbic regions including the ventromedial prefrontal cortex, insula, and amygdala. No study has yet examined regional brain volumes in relation to the two dominant models of emotional intelligence: the Ability model, which posits a set of specific demonstrable capabilities for solving emotional problems, and the Trait model, which proposes a set of stable emotional competencies that can be assessed through subjectively rated self-report scales. In 36 healthy participants, we correlated scores on the Mayer–Salovey–Caruso Emotional Intelligence Test (an Ability measure) and the Bar-On Emotional Quotient Inventory (a Trait measure) with regional brain volumes using voxel-based morphometry. Total Mayer–Salovey–Caruso Emotional Intelligence Test scores were positively correlated with the left insula grey matter volume. The Strategic emotional intelligence subscale correlated positively with the left ventromedial prefrontal cortex and insular volume. In contrast, for the Bar-On Emotional Quotient Inventory, Stress Management scores correlated positively with the bilateral ventromedial prefrontal cortex volume. Amygdala volumes were unrelated to emotional intelligence measures. Findings support the role of the ventromedial prefrontal cortex and insula as key nodes in the emotional intelligence circuitry. *NeuroReport* 23:551–555 © 2012 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Keywords: amygdala, emotional intelligence, insula, somatic marker hypothesis, ventromedial prefrontal cortex, voxel-based morphometry

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Introduction

Although some people cope skillfully with adversity and seem resilient in the face of challenging situations, others have greater difficulty managing their emotions and are prone to poor decision-making under stress. Together, these social, affective, and coping capacities have been described as emotional intelligence. The construct of emotional intelligence comprises a number of traits and competencies that involve attunement to multiple levels of emotional information and the ability to flexibly regulate and use emotions in an adaptive manner to facilitate effective judgment and decision-making, foster relationships, and achieve goals [1–3]. The exact nature of these capacities continues to be debated, with some researchers describing emotional intelligence in terms of trait-like competencies that can be measured through self-report (i.e. Trait models) [4], whereas others have argued that emotional intelligence is only validly conceptualized and measured in terms of demonstrable emotional reasoning abilities, more akin to traditional cognitive approaches to intelligence (i.e. Ability models) [2].

The integration of emotional information with other aspects of cognition appears to rely on the interaction of several key brain regions, particularly the medial orbitofrontal cortex, ventromedial prefrontal cortex, insular cortex, and amygdala [5]. Together, these constitute the Somatic Marker Circuitry [5], which is hypothesized to integrate emotional states, previous learning, and conscious cognition to guide decision-making toward advantageous outcomes [6]. The ventromedial prefrontal cortex appears to be particularly crucial, given its roles in emotional regulation [7], judgment, and advantageous decision-making [8]. The insular cortex is important for processing the interoceptive cues involved in emotion [9,10], and integrating them with ongoing cognition [11]. Despite the burgeoning literature on various social, cognitive, and interpersonal aspects of emotional intelligence and social cognition, there is only limited research into the neurobiological basis of emotional intelligence. Functional neuroimaging has supported the role of the medial prefrontal cortex in emotional intelligence [12,13], and two published studies have examined the correlation between self-reported perceptions of emotional intelligence traits with voxel-wise gray matter volume in the brain [14,15]. Although both studies implicated gray matter volume in the ventromedial prefrontal cortex, the two studies were discordant in the direction of the reported association, and both used only self-report trait measures of emotional intelligence. To our knowledge, no study has yet examined the relationship between brain structure and ability-based measures of emotional intelligence. In the present study, we used voxel-based morphometry to evaluate the relationship between gray matter volume of the Somatic Marker Circuitry and emotional intelligence as measured by

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both the Trait and Ability models. We hypothesized that higher emotional intelligence as assessed by both models, particularly regarding facets involving emotional control, would be associated with greater gray matter volume of the ventromedial prefrontal cortex, insula, and amygdala, as key regions of the Somatic Marker Circuitry.

Methods

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EI, Emotional Intelligence; EQ, Emotional Quotient; EQ-i, Bar-On Emotional Quotient Inventory; MSCEIT, Mayer-Salovey-Caruso Emotional Intelligence Test.

Discussion

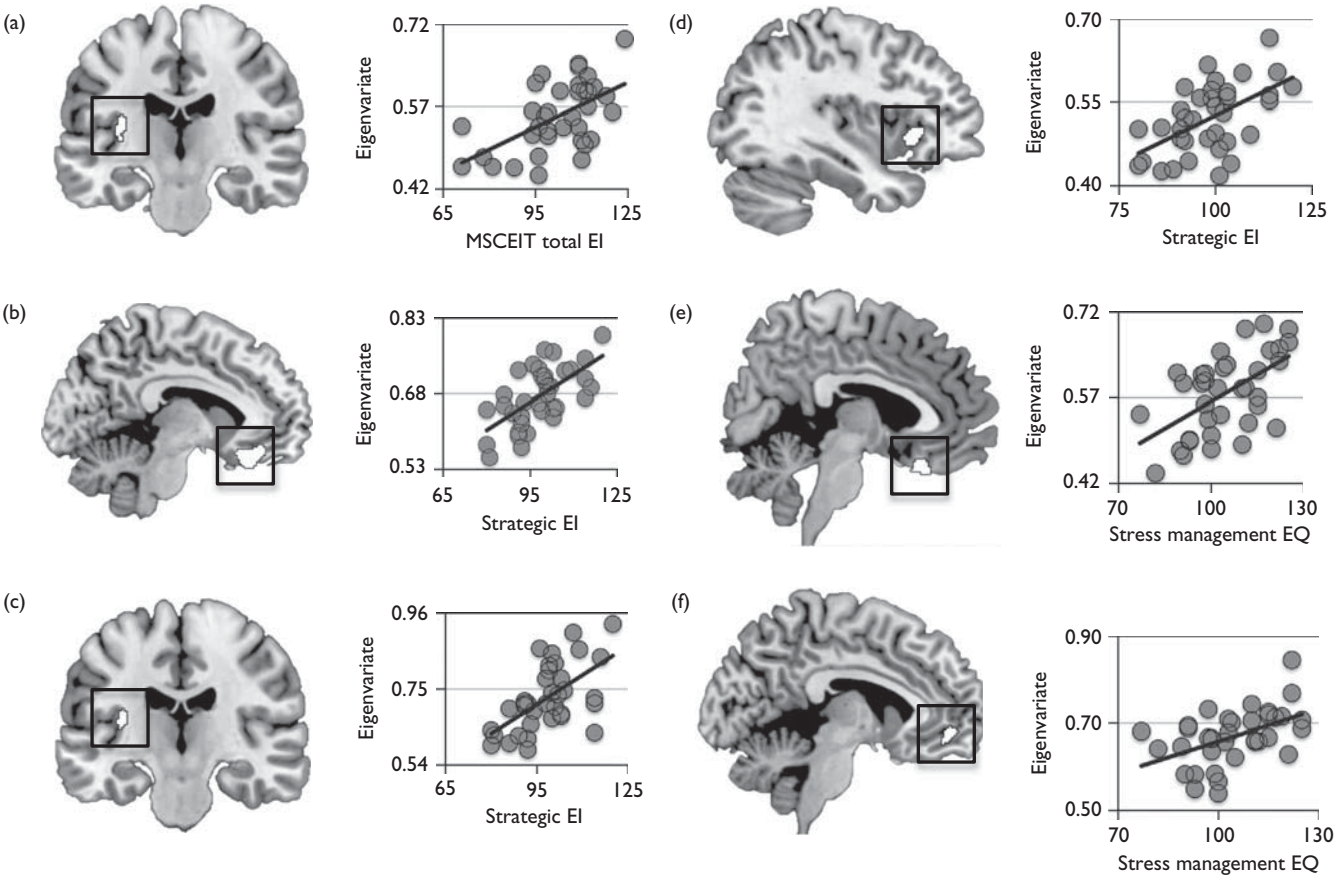
Specific facets of the Ability and Trait models of emotional intelligence correlated positively with gray matter volume in regions of the Somatic Marker Circuitry. Total scores on the MSCEIT, an Ability measure of emotional intelligence, correlated positively with gray matter volume within the left posterior insula, a region implicated in somatic [9] and emotional processing [18], and which may be particularly activated by focused attention toward one's own emotional state [19]. As an Ability measure, the MSCEIT assesses emotional intelligence in terms of measurable performance capacities involved in reasoning about and solving emotional problems, which are divided into two broad areas or domains of functioning. Of the two MSCEIT Area scores, Experiential and Strategic emotional intelligence, only Strategic emotional intelligence was significantly related to gray matter volume in the Somatic Marker Circuitry regions. Strategic emotional intelligence, which involves the ability to understand the meaning of emotional information (e.g. understanding how various emotions are related and what factors affect emotional change) and the ability to regulate emotions in oneself and others (e.g. modulating emotional states to achieve particular goals) [2], was associated with greater gray matter volume in the ventromedial prefrontal cortex, anterior insula, and posterior insula. This is consistent with previous findings suggesting that the ventromedial prefrontal cortex is important for emotional control [7,20], and evidence suggesting that damage to this region may lead to deficits in regulating emotion, poor judgment, and impaired decision-making [8]. Recent functional neuroimaging findings suggest that the ventromedial prefrontal cortex plays a prominent role in resilience against stress and trauma [21], whereas morphometric findings have shown that coping with stress early in life is associated with expansion of ventromedial prefrontal cortex volume in nonhuman primates [22]. Experiential emotional intelligence, which involves perceptual awareness of emotional signals and the ability to use emotions to facilitate thought [2], was unrelated to gray matter volume

Table 2 Gray matter correlates of Emotional Intelligence

			MNI coordinates				
EI measure	Region	Cluster size	*x*	*y*	*z*	*T*	*r*
MSCEIT (Ability Emotional Intelligence)							
Total EI	Posterior insula	159	−32	−19	12	4.66	0.56
Strategic EI	VMPFC	584	−4	39	−15	4.69	0.63
		123	10	58	−14	4.47	0.56
	Posterior insula	111	−32	−19	13	4.38	0.56
	Anterior insula/ventrolateral PFC	225	−38	21	−2	4.31	0.60
EQ-I (Trait Emotional Intelligence)							
Stress Management EQ	VMPFC	185	4	24	−24	4.47	0.56
		110	−8	51	−8	3.73	0.48

EI, Emotional Intelligence; EQ, Emotional Quotient; EQ-i, Bar-On Emotional Quotient Inventory; MNI, Montreal Neurological Institute; MSCEIT, Mayer-Salovey-Caruso Emotional Intelligence Test; PFC, prefrontal cortex; VMPFC, ventromedial prefrontal cortex.

Fig. 1



Brain regions with significant positive correlations between gray matter volume and Emotional Intelligence measures superimposed on a single-subject T1-weighted structural image and corresponding scatterplots. (a) Coronal view of the left posterior insula gray matter volume that correlated with the total MSCEIT emotional intelligence. (b) Sagittal view of the left ventromedial prefrontal cortex (gyrus rectus and medial frontal gyrus, orbital region) gray matter volume that correlated with Strategic emotional intelligence. (c) Coronal view of the left posterior insula gray matter volume that correlated with Strategic emotional intelligence. (d) Sagittal view of the left anterior insula/ventrolateral (inferior frontal gyrus) prefrontal cortex gray matter volume that correlated with Strategic emotional intelligence. (e) Coronal view of the right ventromedial prefrontal cortex (gyrus rectus) gray matter volume that correlated with Stress Management EQ. (f) Sagittal view of the left ventromedial prefrontal cortex (medial frontal gyrus, orbital region) gray matter volume that correlated with Stress Management EQ. EI, Emotional Intelligence; EQ, Emotional Quotient; MSCEIT, Mayer-Salovey-Caruso Emotional Intelligence Test.

in any of the hypothesized regions. This suggests that while the volume of structures within the hypothesized neurocircuitry was associated with reasoning about emotions, it was not related to perception of emotional information or using emotions to facilitate thought. Notably, while the amygdala has also been implicated as an important node of the Somatic Marker Circuitry, volumetric measures of this structure were not significantly related to Ability emotional intelligence measures.

We also examined gray matter volume correlates of Trait emotional intelligence on the EQ-i. Total EQ-i and four of its five subscale scores, including the Interpersonal, Intrapersonal, Adaptability, and General Mood scores, were not significantly correlated with gray matter volume in the hypothesized regions. Higher scores on the Stress Management subscale were, however, significantly correlated with greater gray matter volume within the bilateral ventromedial prefrontal cortex. Persons with high Stress Management scores are reported to cope with stress in an active and resourceful manner while maintaining a positive, composed, and self-confident outlook [4]. This ability to maintain emotional control and demonstrate positive coping and resilience in the face of adversity was reported to a greater degree among those with elevated gray matter volume of ventromedial prefrontal cortex regions, which have previously been implicated in emotional control [7,20,23]. As with the Ability measure of emotional intelligence, amygdala volume was not significantly correlated with Trait emotional intelligence scores.

To our knowledge, this is the first study to examine the brain morphometric correlates of the two dominant models of emotional intelligence by employing widely used, standardized, well-validated, and commercially available assessment instruments. Findings converge on the key

role of the ventromedial prefrontal cortex in emotional intelligence, as gray matter volume in this region was positively correlated with facets of emotional intelligence related to emotional control, regardless of whether assessed via the Trait or Ability models. Higher gray matter volume in ventromedial prefrontal cortex was associated with demonstrated ability to understand and manage emotional information (i.e. MSCEIT Strategic emotional intelligence) and self-reported traits suggestive of the ability to cope with adversity without losing emotional control (i.e. EQ-i Stress Management). A previous study also showed that gray matter volume in this same region was associated with one facet of perceived emotional intelligence that involves directing attention toward conscious subjective emotional experience [15]. Previous work has also suggested that higher Trait emotional intelligence is associated with reduced ventromedial prefrontal cortex and frontal pole activation [12,13], suggesting greater neural efficiency within these prefrontal regions among individuals with higher emotional functioning. The present findings also support the role of the insular cortex in emotional intelligence. We found that greater gray matter volume in the posterior insula, a region important for interoceptive perception [9], and in the anterior insula, a region that is critical for integration of cognition and emotion [11], was associated with higher Total and Strategic emotional intelligence scores. In contrast to the significant correlations between emotional intelligence and gray matter volume in the ventromedial prefrontal cortex and insula, there was no relationship with amygdala volumes. Although the amygdala is part of the Somatic Marker Circuitry, previous morphometric work has also failed to demonstrate volumetric relations between the amygdala and emotional intelligence [14,15]. This may be a consequence of the fact that the amygdala comprises several functionally distinct nuclei, each of relatively small volume compared with the spatial resolution of modern voxel-based morphometry methods, such as those used here. Future work may examine these emotional intelligence measures in groups with various forms of psychopathology, or even study the potential of emotional intelligence to predict resilience against stress or psychiatric disease.

Conclusion

Trait and Ability measures involving emotional regulation facets of emotional intelligence were both related to gray matter volume in the ventromedial prefrontal cortex, whereas only Ability emotional intelligence was specifically associated with gray matter volume in the insular cortex. These findings support the role of the ventromedial prefrontal cortex and insula as key nodes in the Somatic Marker Circuitry, and further suggest that larger volume of these regions in nominally healthy adult participants is associated with greater capacities for understanding and using emotional information and for demonstrating resilience and effective coping in the face of stress and adversity.

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Conflicts of interest

There are no conflicts of interest.

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Self-reported nocturnal sleep duration is associated with next-day resting state functional connectivity

William D. S. Killgore, Zachary J. Schwab and Melissa R. Weiner

Sleep deprivation affects cerebral metabolism and reduces the functional connectivity among various regions of the brain, potentially explaining some of the associated mood and emotional changes often observed. Prior neuroimaging studies have only examined the effects of sleep deprivation or partial sleep restriction on functional connectivity, but none have studied how such connectivity is associated with normal variations in self-reported sleep duration the night before the scan. We examined the relationship between sleep duration and resting state functional connectivity among healthy volunteers who slept at home according to their own schedules. Thirty-nine healthy individuals aged 18–45 (21 females) completed a questionnaire asking about their recent sleep habits and entries in their sleep diary for the previous night, followed by resting state functional MRI at 3 T. Participants reported sleeping between 5.0 and 8.5 h the night before the scan ($M = 7.0$, SD = 0.9). Seed regions were placed in the medial prefrontal cortex and posterior cingulate cortex nodes of the default mode network, regions previously implicated in sleep deprivation. Longer self-reported sleep duration was associated with significantly enhanced functional connectivity between the medial prefrontal cortex and posterior cingulate, as well as greater anticorrelations with parietal, occipital, and lateral prefrontal regions. Findings suggest that even normal variations in sleep duration measured by self-report are related to the strength of functional connectivity within select nodes of the default mode network and its anticorrelated network. *NeuroReport* **23:741–745** © **2012 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

Sleep is vital to normal cognitive functioning [1]. Without adequate sleep, attention and central processing systems are adversely affected [2], potentially leading to deficits in many cognitive and affective capacities [3]. Sleep loss has been associated with slowed response times and increased lapses in vigilant attention [4], memory deficits [5], increased risk taking [6], altered mood and emotional processing [7], and impairments in executive functions such as behavioral inhibition, planning, mental flexibility, and decision making [3,8].

Although alertness and vigilance are the primary capacities impaired by sleep loss [4], some higher cognitive deficits may result from altered functioning in prefrontal executive systems [3,8]. Regional cerebral metabolism appears to be notably reduced within the ventral and medial prefrontal regions after one night of total sleep deprivation [9,10]. One brain system that involves both attention and complex cognition is the default mode network (DMN) and its anticorrelated network (ACN). The DMN is believed to reflect internal spontaneous cognitive activity that occurs in the absence of a focused cognitively demanding task (e.g. resting state), and includes the medial prefrontal cortex (MPFC), posterior cingulate cortex (PCC), and retrosplenial cortex, as primary nodes. In contrast, the ACN reflects the regions that are typically positively activated by mentally engaging tasks, including a bilateral dorsal attention system and a right lateralized ventral attention system. Recent evidence suggests that even one night of controlled sleep deprivation in the laboratory is associated with reduced functional connectivity (i.e. interregional temporal correlations) within the DMN and ACN [11]. Similarly, restriction of sleep to 3.5 h during a single night in the laboratory was also associated with reduced functional connectivity of DMN and ACN nodes [12].

Although experimental laboratory sleep deprivation appears to be associated with reduced functional connectivity in these critical networks, it was of interest to determine whether similar findings would be observed in relation to the normal variability in sleep obtained by most healthy adults living in unconstrained environments and allowed to sleep according to their own schedules. Here, participants reported their previous night's sleep duration on a sleep diary and underwent a resting state functional MRI (fMRI) scan. We hypothesized that greater duration of sleep on the prescan night would be associated with stronger functional connectivity among brain regions associated with the DMN.

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Methods

Participants

Thirty-nine (21 male; 18 female) right-handed, healthy adults ranging in age from 18 to 45 years ($M = 30.4$, SD = 8.7) were recruited from the Boston metropolitan area. Participants were predominantly White (59%), African American (23%), or Asian American (10%), with an average of 15 years of education (SD = 2.0), and were screened by a trained research technician via a detailed series of medical and psychiatric history questions. Participants were excluded for severe medical conditions (e.g. diabetes, heart conditions), history of head injury, loss of consciousness for more than 30 min, seizures, brain tumors, other neurologic conditions, or any prior history of axis I disorders or reported symptoms consistent with such diagnoses. Participants were not currently using any psychoactive medications or illicit substances, and were free from history of drug or alcohol treatment. Alcohol use was required to be lower than Center for Disease Control criteria for excessive drinking (*http://www.cdc.gov/alcohol*). All were self-reported normal sleepers, averaging 5.5–9 h of sleep on weekdays ($M = 7.4$, SD = 0.9) and 4–10 h on weekends ($M = 7.6$, SD = 1.3). Participants were low-to-moderate caffeine users ($M = 107.7$ mg/day, SD = 118.2), and had consumed close to their typical caffeine intake on the day of the scan ($M = 81.6$ mg, SD = 113.3). This research was approved by the McLean Hospital Institutional Review Board. All participants provided written informed consent and were compensated for their time.

Materials and procedure

Participants arrived for the study between 9 and 11 a.m., completed informed consent procedures, and filled-out a questionnaire asking about sleep habits and the number of hours of sleep obtained the preceding night. Between 1 and 3 p.m., participants underwent a series of structural and functional MRI scans including a 6-min resting state fMRI scan with instructions to rest with eyes open.

Magnetic resonance imaging parameters

Data were acquired on a 3 T Siemens Tim Trio scanner (Erlangen, Germany) using a 12-channel head coil. For use in spatial normalization and to remove tissue confounds, structural images were collected using a T1-weighted 3D MPRAGE sequence (TR/TE/flip angle = 2.1 s/2.25 ms/12°) yielding 128 sagittal slices (256 × 256 matrix) with a slice thickness of 1.33 mm and a voxel size of 1 × 1 × 1.33 mm. Resting scan images were collected over 34 transverse interleaved slices using a T2*-weighted blood oxygen level dependent echoplanar imaging sequence (TR/TE/flip angle = 2.0 s/30 ms/90°), with 180 images per slice (3.5 mm thickness, no skip; 22.4 cm field of view; 64 × 64 acquisition matrix).

Image processing

Data were preprocessed using standard algorithms in SPM8, including motion correction, slice-timing correction, coregistration to each subject's anatomical image, spatial normalization, and spatial smoothing using an isotropic Gaussian kernel (full-width at half-maximum = 6 mm, and resliced to 2 × 2 × 2 mm). Functional connectivity analysis was conducted using the Functional Connectivity Toolbox version 13i (*http://www.nitrc.org/projects/conn*). Data were band-pass filtered (0.008, 0.10 Hz), corrected for physiological noise using a CompCor strategy [13], significant principle components of white matter and cerebrospinal fluid were removed, and motion parameters were statistically controlled. Two seed regions were placed corresponding to two primary nodes of the DMN, including the MPFC and PCC. Seed regions were defined as 10 mm spheres located at the coordinates derived from prior published work for the MPFC ($x = -1$, $y = -47$, $z = -4$) and PCC ($x = -5$, $y = -49$, $z = -40$) [14], and implemented as standard regions in the toolbox.

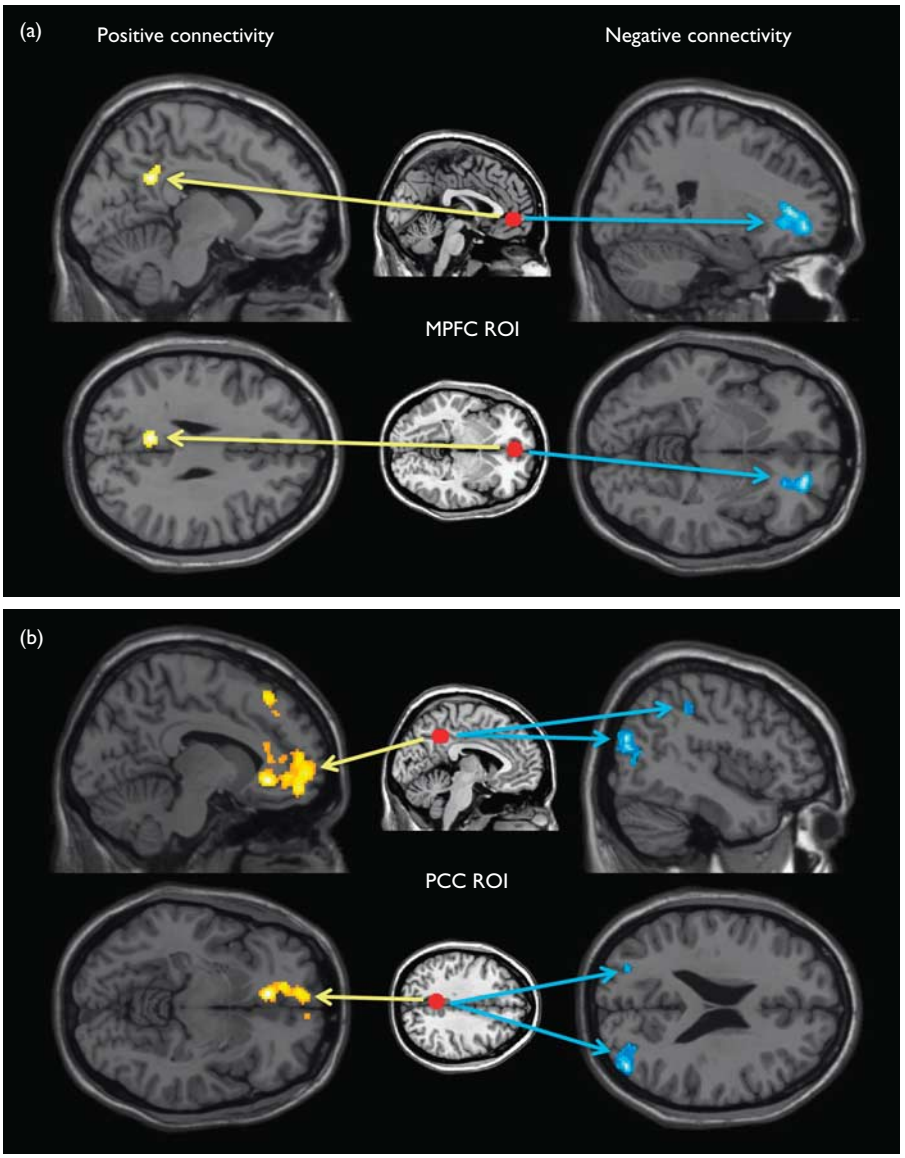
Statistical analysis

In the first level analysis, the residual blood oxygen level dependent signal timecourse from each seed region was extracted and Pearson correlations were computed with all other voxels in the brain to derive connectivity maps. In the second level random-effects analysis, z-score transformed connectivity maps were entered into a general linear model regression analysis evaluating the relationship between sleep the preceding night and the strength of functional connectivity for the two seed regions. In addition, as a control comparison, the same analyses were conducted again using a nonhypothesized predictor variable expected to be unrelated to resting state functional connectivity (i.e. participant self-reported height in inches). Consistent with the standard procedures suggested by the authors of the Functional Connectivity Toolbox (*http://www.nitrc.org/projects/conn*) for seed-to-voxel analyses, connectivity maps were thresholded using a combination of height and extent thresholds to control for false positives. Specifically the correlation maps were interrogated at a height threshold of P less than 0.001 (uncorrected), whereas spatial extent (i.e. cluster size) was simultaneously corrected for family-wise error at P less than 0.05.

Results

Participants all reported obtaining some sleep the night before the scan, ranging between 5.0 and 8.5 h ($M = 7.0$, SD = 0.9). Figure 1 shows that greater duration of self-reported sleep was associated with increased functional connectivity for both nodes of the DMN. Individuals who slept more on the prescan night showed greater positive connectivity between the MPFC seed region and activation within the posterior cingulate gyrus and vermis of the cerebellum, and significant anticorrelations with bilateral activation within the white matter and cortical regions near the medial frontomarginal sulcus and extending posterior to the anterior horn of the lateral ventricles (see Table 1 for coordinates). Similarly, greater

Fig. 1



Self-reported sleep duration correlates with enhanced functional connectivity with two 10 mm spherical seed-regions of interest (ROI) placed at specific nodes of the default mode network, including the medial prefrontal cortex (MPFC) and posterior cingulate cortex (PCC). (a) Self-reported sleep duration correlated with greater positive connectivity between the MPFC seed-ROI and a region in the posterior cingulate gyrus (left) and correlated with greater negative connectivity between the MPFC and a region within the white matter of the lateral prefrontal cortex (right). (b) Self-reported sleep duration was correlated with greater positive connectivity between the PCC seed-ROI and several regions within the rostral and dorsal medial prefrontal cortex (left) and greater negative connectivity with posterior parietal and occipital cortex regions (right).

self-reported sleep duration was positively correlated with greater connectivity between the PCC seed region and several regions of the MPFC (Brodmann Area 10), subgenual anterior cingulate cortex, middle frontal gyrus, and regions of the dorsal and rostral regions of the superior frontal gyrus. Longer sleep duration was associated with significantly greater anticorrelated connectivity between the PCC and bilateral regions of the superior and inferior parietal lobe, middle occipital gyrus, and inferior postcentral sulcus. In contrast, when self-reported sleep was substituted with a control parameter (i.e. participant height) as the covariate of interest, there was no correlation with resting state functional connectivity for either the MPFC or PCC.

Discussion

Longer self-reported sleep duration was associated with significantly greater next-day functional connectivity between specific nodes of the DMN and its ACN. The increase in functional connectivity with additional sleep

Table 1 Regions showing enhanced functional connectivity with longer sleep duration

			MNI coordinates			
Seed region	Target region	Cluster size	*x*	*y*	*z*	*T*
MPFC positive						
	L. cerebellum (vermis)	919	−2	−50	−40	4.75
	L. posterior cingulate	888	−9	−51	29	4.59
MPFC negative						
	R. prefrontal WM	47 970	22	46	−6	5.15
	L. prefrontal WM	17 130	−8	24	10	5.03
PCC positive						
	L. anterior cingulate	12 216	−10	32	−8	6.50
	L. sup. frontal gyrus	15 520	−13	33	55	4.85
	R. sup. frontal gyrus	12 340	13	39	37	4.75
	L. inf. orbital frontal gyrus	671	−34	24	−20	4.69
PCC negative						
	R. mid. occipital gyrus	41 810	−10	32	−8	6.50
	R. sup./inf. parietal cortex	62 160	19	−51	43	5.41
	L. inf. parietal cortex	38 000	−27	−49	49	5.29
	L. sup./mid. occipital gyrus	912	−25	−77	27	4.83

All voxels significant at $P<0.001$, extent corrected at $P<0.05$ for family-wise error. Voxel size = $1 \times 1 \times 1$ mm.
inf., inferior; L, left; MPFC, medial prefrontal cortex; mid., middle; MNI, Montreal Neurological Institute; PCC, posterior cingulate cortex; R, right; sup., superior; WM, white matter.

is particularly remarkable, as our participants were not intentionally sleep deprived, having obtained on average, about the same amount of sleep that is typically reported on weeknights by most healthy American adults (*http://www.sleepfoundation.org*). These findings replicate and extend prior laboratory findings, which have shown that experimentally induced total sleep deprivation [11] and severe restriction of sleep to subnormal levels [12], significantly reduces functional connectivity among DMN circuits. Our findings suggest that even within the range of variability in sleep durations normally experienced by most healthy adults on weeknights, the accumulation of additional sleep up to about 8.5 h appears to be associated with greater functional connectivity within the DMN/ACN circuitry. In contrast, these relationships were not observed when a nonhypothesized control variable was used as a predictor.

The relevance of these findings to actual cognitive performance remains an open question, but emerging evidence suggests that the DMN plays an important role in various states of consciousness, particularly the balance of directed awareness toward the internal versus external milieu [15,16]. We found that longer sleep on the prescan night was associated with stronger positive functional coupling of the anterior region of the DMN (i.e. the MPFC) with the posterior cingulate, and stronger negative coupling with lateral prefrontal regions. Similarly, more sleep was associated with greater positive coupling between posterior cingulate with dorsal and rostral regions of the MPFC and negative coupling with ACN regions such as the parietal attention and occipital sensory cortices. Although the function of the DMN is not fully understood, it appears to be relatively more activated when individuals are engaged in self-referential thought or other inwardly directed mentation and is decreased as the focus of attention is directed outward toward external stimuli or focused on other cognitively challenging tasks [15].

Interestingly, recent evidence suggests that components of the DMN become uncoupled during sedation [17] and with the onset of sleep [18], pointing to its possible role in conscious awareness [12]. Total sleep loss or induced sleep pressure from partial sleep restriction also reduces functional connectivity of these systems [11,12]. Some nodes of the DMN, such as the ventromedial prefrontal cortex, have been hypothesized to play an important role in the ability to integrate emotion and cognition, a synthesis that is believed to be advantageous to effective judgment and decision making [19]. Recent evidence suggests that sleep loss alters functional connectivity between the ventromedial prefrontal cortex and emotion processing regions such as the amygdala [20], which may underlie many of the cognitive-affective deficits often seen during acute sleep deprivation [3], such as impaired moral judgment [21], poor decision making [6,22], increased risk taking [23], and difficulty coping with stress [24]. It is therefore possible that the functional connectivity of these systems may be critical in maintaining normal functioning of cognitive-affective processes, and their alteration by even modest shifts in sleep duration may underlie some of the often experienced changes in mood and cognition that occur on nights when sleep has been truncated.

A major limitation of the present study is the singular focus on resting state connectivity, so the role of sleep duration on the dynamic communication among these networks during cognitive task processing cannot be elucidated. It will be important in future work to explore the effects of various degrees of sleep pressure on the dynamic functional connectivity of these networks during active task engagement. We also highlight the fact that our data are correlational in nature and that causal inferences are not possible in this type of study design. It is, therefore, plausible that instead of greater sleep producing enhanced functional connectivity, it may be that greater connectivity leads individuals to require longer sleep. Additional research will be necessary to determine the causal chain, although when considered in the context of prior work on sleep deprivation and sleep restriction [11,12], our findings support the notion that sleep duration causally affects functional connectivity. Finally, it is important to acknowledge that our estimate of sleep duration was based on self-report, which is admittedly less reliable than objective measures such as electroencephalography or actigraphy. Replication of these findings with more objective measures of sleep will be an important next step. With these limitations in mind, we believe that the present data are compelling and suggest a significant relationship between normal variations in self-reported sleep duration and greater resting functional connectivity among several nodes of the DMN.

Conclusion

Self-reported sleep duration within the bounds of what most healthy adults obtain each day was significantly correlated with resting functional connectivity among several nodes of the DMN and ACN. These findings highlight the important role of sleep in the normal functioning of brain neurocircuitry. Even relatively minor differences in sleep duration may be related to significant differences in the strength of the functional connectivity among these systems.

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Conflicts of interest

There are no conflicts of interest.

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Voxel-based morphometric gray matter correlates of daytime sleepiness

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ABSTRACT

Sleep disorders such as narcolepsy, obstructive sleep apnea, and chronic insomnia have been associated with reduced gray matter volume of the ventromedial prefrontal cortex (VMPFC). Functional neuroimaging and behavioral data also implicate this region as important in sleep-related problems and the ability to resist the impairing effects of sleep loss on cognition. However, no study has linked gray matter volume within this region to normal self-reported levels of daytime sleepiness. We therefore hypothesized that reduced gray matter volume within the VMPFC would be related to greater self-reported levels of general daytime sleepiness, as assessed by the Epworth Sleepiness Scale (ESS) in a sample of 36 healthy non-clinical participants. Using voxel-based morphometry, scores of the ESS were correlated with gray matter volume, after controlling for age, gender, and whole brain volume. Daytime sleepiness correlated negatively with gray matter volume in a cluster of voxels within the left gyrus rectus and medial orbitofrontal cortex. Findings converge with prior evidence to suggest that the VMPFC and medial orbitofrontal cortex may play a particularly important role in sleep–wake related phenomena including sleep disorders and trait-like individual differences in vulnerability to the impairing effects of sleep deprivation on neurobehavioral performance, and also in normal variations in self-reported daytime sleepiness.

1. Introduction

Sleepiness refers to the biological pressure to fall asleep and can be differentiated from other related concepts such as fatigue, tiredness, or low energy, which do not necessarily reflect sleep propensity [1]. While excessive sleepiness can be a symptom of a number of medical disorders, even healthy normal individuals report feeling sleepy immediately following awakening, during early morning hours, or when the accumulated sleep debt is extended sufficiently beyond normal [14]. Without sufficient nocturnal sleep, most individuals will report increased daytime sleepiness on subjective measures and will show a shortened objective latency to fall asleep [23]. Thus, the most common and obvious effect of sleep loss is sleepiness.

Behavioral and neuroimaging studies have shown that insufficient sleep can have a number of adverse effects on brain functioning. Total overnight sleep deprivation is associated with significant reductions in cerebral glucose metabolism, particularly within the prefrontal cortex [25,29]. These declines appear to be especially prominent in the ventromedial prefrontal cortex (VMPFC) and orbitofrontal cortex (OFC) regions [25]. Furthermore, behavioral tasks sensitive to dysfunction within VMPFC and OFC, such as emotional decision-making, moral judgment, and olfactory perception, seem to be particularly sensitive to sleep deprivation [13,16–18,15]. In particular, tasks involving sensitivity to rewards and punishments and their valuation during decision-making processes appear to be adversely affected by sleep deprivation and are often associated with altered functional activation within the VMPFC [20,27], a region which includes subgenual cingulate cortex, gyrus rectus, and medial orbitofrontal regions. Behavioral data further suggest that poorer baseline performance on tasks sensitive to OFC integrity is predictive of vulnerability to the impairing effects of sleep loss on vigilance performance [19]. Together, the data suggest that sleep loss has a particularly notable effect on VMPFC functioning.

While it is clear that sleep loss can affect brain functioning in the VMPFC, it is not clear whether sleepiness or sleep-related problems are related in a more durable way to measureable differences in brain structure of this region. Only a small handful of studies have examined the relationship between sleep-related variables and brain structure. Using voxel-based morphometry (VBM), one study showed that patients with narcolepsy and cataplexy showed significant reductions in gray matter concentration within VMPFC, particularly the left gyrus rectus [11]. Similarly, a separate study of patients with obstructive sleep apnea (OSA) showed reduced gray matter concentrations in the left gyrus rectus as well

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[12]. Finally, reduced gray matter volume was also found in the left OFC among a sample of patients with chronic insomnia [2]. These findings suggest that morphology of the VMPFC may be either affected by, or may itself contribute to some sleep-related difficulties. To our knowledge, no study has examined the relationship between brain structure and self-reported daytime sleepiness among healthy normal individuals. Therefore, we correlated gray matter volume (GMV), as measured by VBM, with self-ratings of daytime sleepiness, hypothesizing that higher ratings of general sleepiness would be associated with reduced GMV within the VMPFC.

2. Methods

2.1. Participants

Thirty-six right-handed volunteers (mean ± standard deviation = 30.0 ± 8.9 years, range 18–45; 20 males; 16 females) were recruited from the local area of Boston, MA, via flyers posted in community centers and advertisements in local newspapers and the Internet. Participants received payment for their participation. All participants underwent a detailed intake interview that included screening questions from the Structured Clinical Interview for DSM-IV Disorders (SCID-I/P) [7] and questions on prior psychological, psychiatric or other mental health counseling and diagnoses. Exclusion criteria were a history of Axis I disorder, neurological illness or head injury, sleep-related disorder, current use of psychotropic medication or other medications known to affect functional neuroimaging, or current chemotherapy or radiation therapy. This study was approved by the McLean Hospital Institutional Review Board. All participants provided written informed consent.

2.2. Materials and procedure

On the day of magnetic resonance scanning, each participant completed the Epworth Sleepiness Scale (ESS), a self-report measure of typical or trait-like daytime sleepiness [8]. This self-administered inventory consists of eight situations (e.g. sitting and reading; as a passenger in a car for an hour without a break) which participants rate for the chance of dozing on a 4-point scale (0 – would never doze, 1 – slight chance of dozing, 2 – moderate chance of dozing, 3 – high chance of dozing). A sum score is calculated (maximum: 24), whereby a high score reflects greater daytime sleepiness. Volunteers also completed an information questionnaire about their sleep the night before and caffeine intake during the hours prior to the scan. The ESS has been shown to have good internal consistency reliability (α ranging from .70 to .88) [9,24], and shows high test–retest reliability following a 5-month interval ($r = .82$) [9], suggesting that the construct of sleepiness measured by the scale is highly stable. The ESS also correlates significantly with other subjective and objective measures of sleep quality [4,24].

2.3. MRI parameters

Participants underwent structural magnetic resonance imaging at 3.0 T (SIEMENS Tim Trio) using a 12-channel head coil. Using a T1-weighted three-dimensional MPRAGE sequence (TR/TE/flip angle = 2.1 s/2.25 ms/12°), 128 slices were obtained in the sagittal plane (256 × 256 matrix) with a slice thickness of 1.33 mm and a voxel size of 1 mm × 1 mm × 1.33 mm.

2.4. Voxel-based morphometry (VBM)

Analysis of gray matter volumes was undertaken using voxel-based morphometry (VBM) as implemented in the VBM8 toolbox (http://dbm.neuro.uni-jena.de/vbm.html) in SPM8 (Wellcome Department of Imaging Neuroscience Group, London, UK; http://www.fil.ion.ucl.ac.uk/spm). Preprocessing was completed using the VBM8 default settings for a non-linearly modulated normalized VBM (i.e., total brain volume served as a covariate). In brief, T1-weighted structural images were DARTEL-normalized to the standard stereotaxic space of the Montreal Neurological Institute (MNI), resliced to 1.5 mm × 1.5 mm × 1.5 mm, and then segmented into gray matter, white matter and cerebrospinal fluid. Following preprocessing, data quality checks that are part of the default VBM8 data analysis (i.e., inspection of all normalized bias-corrected volumes for artifacts; visualization of covariance between normalized gray matter volumes) did not identify artifacts or outliers. Spatial smoothing of the normalized gray matter images was conducted by application of an 8 mm full-width at half-maximum (FWHM) Gaussian kernel.

2.5. Statistical analysis

The Shapiro–Wilk Test in SPSS 16.0 was used to assess normal distribution of ESS scores. To evaluate the relationship between ESS scores and regional GMV, the normalized and smoothed gray matter images were entered into a random effects multiple regression analysis (absolute threshold: 0.2) in SPM8 with age and gender included as nuisance covariates. Regression diagnostics including Cook's distance were run in SPSS 16.0 to identify outliers. For our specific hypothesis regarding the VMPFC, data were evaluated at an initial threshold of $p < .001$ (uncorrected), with an extent $k \geq 40$ voxels, and then a small volume correction (SVC) was applied at a threshold of $p < .05$ within bilateral 10 mm spheres centered on the VMPFC coordinates showing the greatest sensitivity to sleep deprivation as reported in the Thomas et al. [25] study of glucose metabolism (i.e., Talairach coordinates, $x = -12$, $y = 24$, $z = -20$; $x = 12$, $y = 16$, $z = -20$). Whole brain analyses of all other significant regions are also reported ($p < .001$, uncorrected, $k \geq 30$), along with separate post hoc analyses by gender. Because these latter analyses were not hypothesized a priori, they are presented only for completeness of reporting, but are not interpreted.

3. Results

Participants reported obtaining 7.0 ± 1.0 h of sleep the night before testing and consumed an average of 74.5 ± 105.2 mg (range: 0–275) of caffeine on the day of their assessment. The mean score on the ESS was 5.4 ± 3.2 (range: 0–14), and was normally distributed ($W = .96$, $p = .16$). There was no significant correlation between ESS scores and self-reported sleep the previous night ($r = -15$, ns) or caffeine intake ($r = -11$, ns) on the day of testing, suggesting that neither of these variables significantly influenced sleepiness ratings.

Consistent with our hypothesis, the data showed that typical daytime sleepiness was significantly negatively correlated with GMV for a cluster of 48 voxels within the left VMPFC (Fig. 1), which remained significant with a small volume correction (FWE, $p = .016$). Regression diagnostics did not identify outliers that may have biased regression findings ($D = 0.04$; range: .00–.63). There were several other regions that also emerged as significant ($p < .001$, uncorrected, $k \geq 30$) in the whole brain analyses and are listed in Table 1 for completeness, although none of these survived FWE correction for multiple comparisons ($p < .05$).

Although not hypothesized, we also undertook separate exploratory post hoc analyses of the data to determine whether the correlation between ESS and gray matter volume within the VMPFC was similar for men and women. For men, the negative correlation was significant within a cluster of 288 voxels of the left

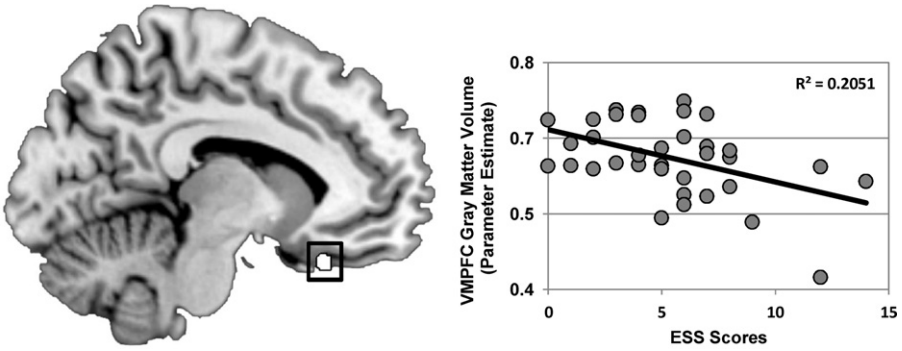

Fig. 1. Sagittal view of the left VMPFC (gyrus rectus) cluster that was inversely correlated with daytime sleepiness and the corresponding scatterplot showing the relationship between ESS and average gray matter volume for the cluster located at MNI coordinates $x = -9$, $y = 27$, $z = -26$.

VMPFC [MNI: $x = -15$, $y = 27$, $z = -21$], and remained significant following small volume correction (FWE, $p < .001$). In contrast, this relationship was not significant among the smaller female sample.

4. Discussion

As hypothesized, reduced GMV in the left VMPFC was significantly related to greater self-reported daytime sleepiness on the ESS. In fact, the region of reduced volume was near the same coordinate location as that which has previously been associated with the greatest medial OFC reductions in absolute glucose metabolism following 24 h of sleep deprivation [25]. The region of reduced GMV was also proximal to an area of the VMPFC that has been implicated in altered decision-making during sleep deprivation [27], and which shows reduced GMV in patients with narcolepsy [11], sleep apnea [12], and chronic insomnia [2]. Notably, a recent neuroimaging study also demonstrated that the wake-promoting agent modafinil leads to increased functional activation within regions of the VMPFC and medial OFC that essentially encompass the same region reported in the present study [10]. The OFC also shows the greatest relative change in A_1 adenosine receptor (A_1AR) upregulation following a night of total sleep deprivation [6], a process that is believed to contribute directly to homeostatic sleep regulation and to modulate the effects of caffeine on alertness. Overall, the converging evidence points to an important role for the VMPFC/medial OFC regions in conditions that may affect sleepiness and wakefulness.

Interestingly, the VMPFC/OFC region has not been directly implicated in basic arousal or alertness, but does show significant covariation of activation across various stages of sleep and conscious wakefulness [3,21]. Recent data from our group suggest that poorer baseline functioning on tasks associated with OFC integrity is associated with greater vulnerability to the adverse effects of sleep deprivation on psychomotor vigilance performance [19]. In the context of those prior findings, the present data raise the possibility that individual variation in GMV of the VMPFC/OFC may contribute to the well-documented trait-like individual differences in the ability to resist the cognitively impairing effects of sleep deprivation [26].

Although reduced GMV in the VMPFC was clearly related to increased daytime sleepiness in the present study, the mechanisms underlying this relationship remain uncertain. The participants in the present study were not sleep deprived, and neither total sleep time the night before the study nor caffeine intake on the day of the study was related to self-reported sleepiness. It is possible that increased scores on the ESS reflect chronic sleep debt, which over extended periods might lead to reduced GMV in the VMPFC through cellular apoptosis or which may affect gray matter development during sensitive periods. This explanation, however, appears to be contradicted by several animal studies which suggest that chronic sleep restriction has no adverse effect on neuronal health [5], and may, in some instances, be mildly protective against neurotoxicity [22] and inflammatory processes [28]. Thus, a more tenable explanation would be that smaller GMV within VMPFC/medial OFC regions might be a pre-existing condition that contributes to the vulnerability to excessive daytime sleepiness or other sleep-related problems. Ultimately, this question would be best addressed by longitudinal research tracking both GMV and sleep-related variables. Future research may address the potential of this region as a marker for susceptibility to sleep-related disorders or as a target for possible neurobiological intervention among such populations. The present study was also limited by the relatively small sample size, which may have reduced statistical power to detect some associations. Finally, although not hypothesized, post hoc analyses revealed that the correlation between daytime sleepiness and VMPFC gray matter volume was significant only among males when the group was divided by gender. However, because this was not hypothesized *a priori* and due to the reduction in power that occurred when the sample was divided, these differences cannot be validly interpreted without replication. However, the possibility of gender differences in these relations should be addressed in future research.

Table 1
Regional correlations between ESS scores and GMV.

Region of activation	Volume	*x*	*y*	*z*	*T*-score
Positive correlations					
R. superior occipital gyrus	157	24	−76	33	5.44
L. calcarine cortex	187	−18	−70	10	4.67
L. cuneus	135	−3	−78	21	4.33
L. superior frontal gyrus	72	−24	0	45	4.19
Negative correlations					
R. cerebellar crus area 2	373	20	−79	−32	3.86
R. cerebellum area 8	58	30	−65	−50	3.79
L. gyrus rectus/sup orbitofrontal gyrus	48	−9	27	−26	3.78*

Notes: L, left hemisphere; R, right hemisphere; Atlas coordinates are listed in the standard space of the Montreal Neurological Institute (MNI). Volumes are in voxels (1.5 mm × 1.5 mm × 1.5 mm). All clusters are significant at $p < .001$ (uncorrected), $k \geq 40$. ESS = Epworth Sleepiness Scale; GMV = Gray Matter Volume.
* $p < .05$ (small volume corrected).

5. Conclusion

In a sample of healthy normal individuals, reduced GMV of the left VMPFC region was significantly correlated with increased self-reported daytime sleepiness. The anatomical concordance of this region with similar loci reported using a variety of neuroimaging and behavioral techniques suggest that the VMPFC/medial OFC may play a particularly important role in the individual expression of

sleep–wake related phenomena. Exploration of the potential role of this region as a focus for treatment of sleep and arousal problems is warranted.

Conflicts of interests

None declared.

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SEX DIFFERENCES IN THE ASSOCIATION BETWEEN PHYSICAL EXERCISE AND IQ[1]

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Summary.—Previous research suggests that physical exercise may have beneficial effects on cognitive performance in children and the elderly, but little research has yet examined these associations in healthy adults. It was hypothesized that self-reported frequency and duration of physical exercise would correlate positively with measured intelligence on the Wechsler Abbreviated Scale of Intelligence in healthy young to middle aged adults (25 men, 28 women). Although there was a modest positive association between physical exercise and intelligence (IQ) for the group as a whole, when examined separately by sex, greater physical activity was associated with higher intelligence scores for women, whereas exercise level was essentially unrelated to intelligence among men. These associations remained consistent even after controlling for demographic and socioeconomic factors. The association between exercise and IQ appears to be moderated by sex in healthy adults, possibly through its effects on glucoregulation, insulin sensitivity, or other factors that differ between men and women.

Regular exercise and physical activity have numerous long-term health benefits. Physical activity has been associated with cardiovascular health (Shiroma & Lee, 2010), and reduced risk of type II diabetes (Laaksonen, Lindstrom, Lakka, Eriksson, Niskanen, Wikstrom, *et al.*, 2005), osteoporosis (Gomez-Cabello, Ara, Gonzalez-Aguero, Casajus, & Vicente-Rodriguez, 2012), some cancers (Lee, 2003), and psychiatric problems (Knochel, Oertel-Knochel, O'Dwyer, Prvulovic, Alves, Kollmann, *et al.*, 2012). Moreover, emerging research also points to the beneficial effects of physical activity on cognitive performance (Hillman, Erickson, & Kramer, 2008; Voss, Nagamatsu, Liu-Ambrose, & Kramer, 2011). The majority of human research has focused on the relationship between physical activity and intelligence in school age children or how exercise may stave off cognitive decline in the elderly. For instance, considerable evidence now suggests that physical activity is associated with better performance among children in school or on standardized tests (Castelli, Hillman, Buck, & Erwin, 2007; Chomitz, Slining, McGowan, Mitchell, Dawson, & Hacker, 2009; Van Dusen, Kelder, Kohl, Ranjit, & Perry, 2011), with cardiovascular fitness and aerobic capacity generally showing the strongest relation to academic performance (Fedewa & Ahn, 2011; Van Dusen, *et al.*, 2011).

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Similarly, aerobic fitness in children is associated with better performance on neuropsychological tests and measures of brain structure and function (Buck, Hillman, & Castelli, 2008; Chaddock, Pontifex, Hillman, & Kramer, 2011; Voss, Chaddock, Kim, Vanpatter, Pontifex, Raine, *et al.*, 2011). Recent studies of school age children suggest that physical exercise interventions result in improved spatial working memory and simple attention (Fisher, Boyle, Paton, Tomporowski, Watson, McColl, *et al.*, 2011), as well as improved executive functioning and enhanced functional activation of the prefrontal and parietal cortices (Davis, Tomporowski, McDowell, Austin, Miller, Yanasak, *et al.*, 2011). Preliminary evidence also suggests that increasing physical activity in children can lead to improvements on indices of fluid intelligence (Reed, Einstein, Hahn, Hooker, Gross, & Kravitz, 2010), but little is known about the effects of exercise on well normed and standardized measures of intellectual ability such as the Wechsler scales or Stanford-Binet tests.

Exercise has also been shown to improve neuropsychological and cognitive functioning in the elderly (Molloy, Beerschoten, Borrie, Crilly, & Cape, 1988), and there is some evidence that physical activity may even lead to enhanced brain volume over time in healthy geriatric individuals (Mortimer, Ding, Borenstein, Decarli, Guo, Wu, *et al.*, 2012). Elderly women in their 80s who had greater activity levels, as quantified by actigraphy, showed better performance on mental status and cognitive set-shifting tasks (Barnes, Blackwell, Stone, Goldman, Hillier, & Yaffe, 2008). A recent study showed that a six-month intervention consisting of low to moderate physical activity yielded significant improvement in memory performance and increased gray matter volume within prefrontal and cingulate cortices among elderly participants (Ruscheweyh, Willemer, Kruger, Duning, Warnecke, Sommer, *et al.*, 2011). Similarly, a randomized trial of physical activity among elderly individuals was associated with significant improvements in cognitive functioning at one-year, including psychomotor processing speed, auditory recall, and Stroop performance (Williamson, Espeland, Kritchevsky, Newman, King, Pahor, *et al.*, 2009), and moderate to high physical activity levels have been associated with reduced risk of cognitive decline over a two year period compared to inactive individuals (Etgen, Sander, Huntgeburth, Poppert, Forstl, & Bickel, 2010). Recent evidence in older adults also suggests that there may be sex differences in the beneficial effects of exercise on cognitive abilities, with the greatest positive effects observed among women (Middleton, Kirkland, & Rockwood, 2008).

In contrast to the large amount of data suggesting a relationship between physical activity and cognition in children and geriatric samples, there has been comparatively little research on this topic in healthy adult

populations. Notably, a recent large-scale population study of male Swedish military conscripts showed that cardiovascular fitness at age 18 years was significantly related to several cognitive abilities, including higher scores on an index of intelligence (Åberg, Pedersen, Toren, Svartengren, Backstrand, Johnsson, *et al.*, 2009). Moreover, examination of a subset of the sample comprising monozygotic twin pairs revealed that more than 80% of the relation between cardiovascular fitness and cognition was accounted for by environmental rather than genetic factors. That study included a number of tasks assumed to measure intellectual functioning, but no study has yet evaluated the association between exercise and intelligence in healthy adults using a well established, psychometrically validated scale of intelligence, such as one of the Wechsler scales. Furthermore, no study has examined the role of sex as a moderator of the relationship between physical activity and intelligence in healthy adults. Here, the relation between physical activity and measured intellectual ability was studied in a sample of young to middle-aged adult men and women, using a well-validated, highly reliable, and individually administered scale of intelligence.

Method

Participants

Fifty-three healthy adults (25 men, 28 women), ranging in age from 18-44 years were recruited from the Boston metropolitan area via internet advertisements and flyers. Participants had no history of serious or chronic diseases, neurological, psychiatric, or substance use disorders (including alcohol and illicit drugs) as assessed by telephone screening. The Body Mass Index (BMI) of participants was within the normal range ($M = 24.3$, $SD = 3.2$). Participants were predominantly Euro-American (62.3%), although other ethnic groups were represented, including African American (17.0%), Asian American (11.3%), Hispanic/Latino (5.7%), and Other (3.8%). Men and women did not differ significantly with regard to age, body mass, or ethnicity (all ps $> .05$). To evaluate the contribution of socioeconomic status and neighborhood poverty on the relation between exercise and intelligence, data regarding median inflation-adjusted 12-month household income and the percentage of the participant's neighborhood below the poverty line (U.S. Census Bureau, 2010) were extracted based on census tract of home address. On average, men lived in neighborhoods where the median income was $73,718, while women lived in neighborhoods with a slightly lower income of $59,263, ($p = .05$), although the proportion of the population living below the poverty line was not significantly different between the two groups. All participants provided written informed consent and were compensated for their time.

Materials and Procedure

Participants completed a brief questionnaire about their exercise habits, including their average number of workouts per week and the average number of minutes of exercise per workout (see Table 1). The total hours of exercise per week was calculated as the product of those two variables for each individual. Intelligence quotient (IQ) was then individually assessed with the Wechsler Abbreviated Scale of Intelligence (WASI; Pearson Assessment, Inc., San Antonio, TX), which provides scores for Full Scale IQ, Verbal IQ, and Performance IQ. The WASI is one of the most widely used intelligence scales in the world and has reported reliability of .98 for Full Scale IQ, with extremely high test-retest reliability, and correlates .92 with the more comprehensive Wechsler Adult Intelligence Scale-III (WAIS; Pearson Assessment, Inc., San Antonio, TX), the current gold standard in intelligence testing. A trained and experienced bachelor's level research assistant who was blind to the study hypotheses administered the WASI under the supervision of a licensed doctoral level neuropsychologist.

Analysis

Pearson correlations were used to evaluate the linear association between exercise and IQ variables. Furthermore, based on responses to the exercise questionnaire, participants were divided into three categories of exercise level: None (0 minutes per week; $n = 11$), Low-Moderate (1–180 minutes per week; $n = 21$), High (>180 minutes per week; $n = 21$). These categories were used in a series of three 2 (sex) × 3 (exercise level) analyses of covariance (ANCOVAs) with Full Scale, Verbal, and Performance IQ as dependent variables. To control for possible socioeconomic and demographic factors on intelligence and exercise behavior, the following covariates were entered in the model: age, BMI, neighborhood median household income, percentage of the neighborhood below the poverty line, and minority ethnic status.

Results

Total Sample Correlations

Men and women did not differ significantly with regard to age, education, measures of intelligence, or frequency of workouts, although men showed a longer duration of each workout session and more total minutes of weekly exercise (see Table 1). For the sample as a whole, however, the frequency of workouts per week was significantly correlated with Full Scale IQ ($r = .42$, $p = .002$), Verbal IQ ($r = .35$, $p = .01$), and Performance IQ ($r = .43$, $p = .001$). Of note, these correlations remained significant in partial correlation analysis after controlling for socioeconomic and demographic variables including age, BMI, neighborhood median household income,

TABLE 1
DESCRIPTIVE STATISTICS AND PEARSON CORRELATIONS BETWEEN SELF-REPORTED PHYSICAL ACTIVITY AND INTELLIGENCE QUOTIENT (IQ) BY SEX

Variable	Men ($n = 25$)		Women ($n = 28$)		Group Difference p
	M	*SD*	*M*	*SD*	
Means					
Age	30.8	8.7	28.0	6.3	.18
Education	14.8	2.0	15.5	2.2	.26
Full Scale IQ	113.0	15.3	110.0	17.0	.52
Exercise Sessions per week	3.5	2.2	3.0	2.3	.41
Minutes per session	58.9	42.3	36.9	24.0	.02*
Minutes per week	252.1	213.1	132.1	102.5	.01*
Pearson Correlation					
Correlations with Full Scale IQ					
Exercise Sessions per week	.09		.67‡		.01
Minutes per session	−.22		.36		.04*
Minutes per week	−.18		.63‡		.002*
Correlations with Verbal IQ					
Exercise sessions per week	.17		.49*		.20
Minutes per session	−.14		.18		.28
Minutes per week	−.13		.47*		.03*
Correlations with Performance IQ					
Exercise Sessions per week	−.04		.72‡		.001†
Minutes per session	−.30		.48*		.004†
Minutes per week	−.23		.68‡		.0004‡

Note.—Correlations were compared via Fisher's *r*-to-*z* transform. *$p < .05$. †$p < .005$. ‡$p < .001$.

percentage of the neighborhood below the poverty line, and minority ethnic status (all ps $< .05$). In contrast, the number of minutes of exercise per workout session and the total minutes of exercise per week were not significantly correlated with IQ for the sample as a whole and were unchanged when socioeconomic and demographic variables were statistically controlled.

Correlations by Sex

As evident in Table 1, the magnitude of the aforementioned associations differed significantly between men and women. Overall, correlations between these variables were consistently nonsignificant for men but were significant and moderate to high for women for Full Scale IQ and Performance IQ, but weak for Verbal IQ. These relationships did not change markedly when socioeconomic and demographic variables were statistically controlled, with most partial correlations showing a modest but slight increase in magnitude. These findings provide further support for the link between physical activity and IQ, but also suggest that these relationships may be moderated by sex.

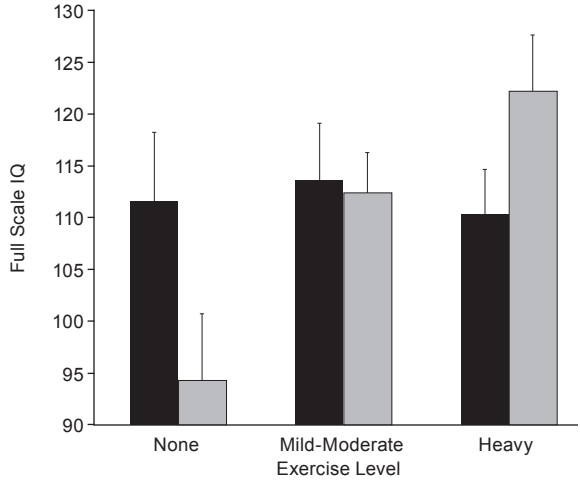

FIG. 1. Interaction between level of exercise and sex on Full Scale Intelligence Quotient (IQ) scores. Men (■); Women (▒).

Exercise Level by Sex

To more effectively evaluate the relation between exercise and intelligence, the sample was divided into three exercise level categories and compared using ANCOVA, with socioeconomic and demographic variables held constant. As evident in Fig. 1, there was a significant interaction between sex and exercise category ($F_{2,42} = 3.21$, $p = .05$, partial $\eta^2 = 0.13$). Whereas men showed no significant effect of exercise level on intelligence, women showed a trend of increasing intelligence with more exercise ($F_{2,42} = 5.28$, $p = .009$, partial $\eta^2 = 0.20$). *Post hoc* comparisons revealed that women who exercised at low-moderate ($p = .02$) and high ($p = .002$) levels had significantly higher Full Scale IQ than those who did not exercise at all. For Verbal IQ, there was no significant main effect of sex or exercise group, and no significant interaction between these variables. However, for Performance IQ, there was a significant interaction between sex and exercise level ($F_{2,42} = 7.12$, $p = .002$, partial $\eta^2 = 0.25$). Fig. 2 shows that there was no effect of exercise level on Performance IQ in men, whereas women showed significantly greater ability with increasing exercise ($F_{2,42} = 10.40$, $p = .0002$, partial $\eta^2 = 0.33$). *Post hoc* comparisons revealed that women who exercised at low-moderate and high levels had significantly higher Performance IQ than those who did not exercise at all ($p < .001$). Furthermore, women who did not exercise showed lower Performance IQ than men who did not exercise ($p < .006$), while women who were heavy exercisers tended to score higher than men who exercised at a similar level ($p < .02$).

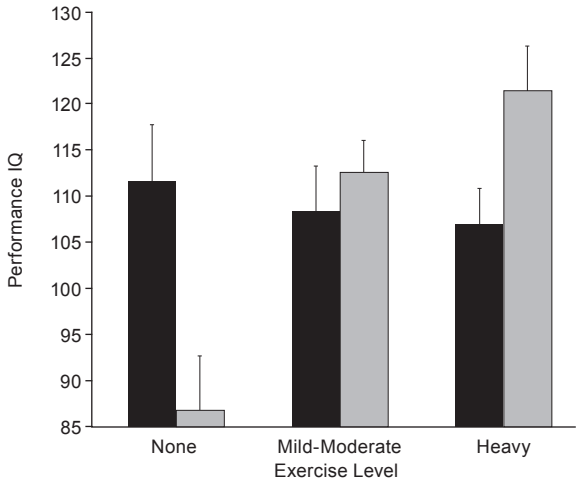

FIG. 2. Interaction between level of exercise and sex on Performance Intelligence Quotient (IQ) scores. Men (■); Women (□).

DISCUSSION

In a cross-sectional sample of healthy adults, those who exercised more frequently tended to have higher measured intelligence, including Full Scale, Verbal, and Performance IQ, while total minutes of exercise per workout or total minutes per week were unrelated to IQ. Notably, however, the strength of these associations was moderated by the sex of the participant, with women showing highly significant correlations between measures of intelligence and both workout frequency and total time spent exercising per week. Furthermore, the correlations remained statistically significant even after controlling for a variety of demographic and socioeconomic factors that could potentially affect physical activity or intelligence as measured by standardized tests. Men, on the other hand, showed no significant correlations between physical exercise and intelligence in this sample. On the whole, similar findings emerged when the data were grouped according to broad exercise categories (i.e., none, low to moderate, high) and subjected to an analysis of covariance, controlling for demographic and socioeconomic variables, with women who exercise showing significantly greater full scale and performance IQ scores than those who did not report that they engaged in physical activity. For men, these variables appeared to be unrelated. Overall, these findings suggest that physical exercise is significantly related to relatively stable intellectual capacities among healthy adults, but that this relationship appears to be moderated by the sex of the individual.

The present findings are consistent with prior work in children and

older adults showing that physical activity leads to improvements in cognitive functioning (Ahn & Fedewa, 2011) and confers some protection against the cognitive declines of aging (Colcombe & Kramer, 2003; Jedrziewski, Ewbank, Wang, & Trojanowski, 2010; Voss, Nagamatsu, *et al.*, 2011). Indeed, considerable evidence now suggests that physical exercise is beneficial for cognition and may be associated with actual neuroplastic changes in brain structure and concomitant changes in functioning (van Praag, 2009). Aerobic training, in particular, appears to be associated with enhanced cognition, and has been associated with improved memory performance (Voss, Nagamatsu, *et al.*, 2011). Physical exercise leads to greater cardiovascular fitness in general (Shiroma & Lee, 2010), and has been shown to increase blood flow within the dentate gyrus of the hippocampus in particular, a cerebral structure that is critical for memory formation and recall (Pereira, Huddleston, Brickman, Sosunov, Hen, McKhann, *et al.*, 2007). In addition to its effects on cerebral blood flow, animal research has also pointed to a number of neurogenerative and neuroprotective effects of physical activity. Aerobic exercise has been shown to increase neurogenesis of hippocampal neurons (van Praag, Christie, Sejnowski, & Gage, 1999; van Praag, Kempermann, & Gage, 1999), and appears to influence long-term potentiation (O'Callaghan, Ohle, & Kelly, 2007), both of which may contribute to some aspects of memory performance. In one recent study, a controlled trial of aerobic exercise led to a 2% increase in hippocampal volume, which was accompanied by improved spatial memory (Erickson, Voss, Prakash, Basak, Szabo, Chaddock, *et al.*, 2011). Physical exercise has also been shown to increase the proliferation of new blood vessels within the brain (Voss, Nagamatsu, *et al.*, 2011), a finding that may play a role in cognitive functioning. The brain may also benefit from neuroprotective effects of exercise, such as its reported ability to reduce oxidative stress (Cotman, Berchtold, & Christie, 2007) and to increase levels of growth factors, including brain-derived neurotrophic factor (BDNF; Knaepen, Goekint, Heyman, & Meeusen, 2010), which is critical for brain metabolism and neurogenesis (Jak, 2012). Physical activity may also be protective against neuronal loss with aging, as structural neuroimaging studies have also shown that older adults who exercise had less volume reduction in the brain compared to less active individuals (Colcombe, Erickson, Raz, Webb, Cohen, McAuley, *et al.*, 2003). Thus, the present findings are well aligned with prior works, which have shown that physical activity, particularly aerobic exercise, is associated with changes in brain structure and function that are associated with better cognitive performance.

The present results also showed that the relationship between physical exercise and measured intelligence was most evident for women compared to men. Prior studies have also suggested that the effects of physical

exercise on cognition appear to be most evident in female samples (Colcombe & Kramer, 2003; Middleton, *et al.*, 2008). A recent controlled trial of aerobic exercise in elderly adults showed that the benefits were primarily observed among women, particularly for cognitive variables involved in executive functions such as selective attention, processing speed, cognitive flexibility, and search efficiency (Baker, Frank, Foster-Schubert, Green, Wilkinson, McTiernan, *et al.*, 2010). While the basis for the sex differences in responses to exercise remain uncertain, some evidence suggests that it may be due in part to sex-related differences in the responses of glucometabolic and hypothalamic-pituitary-adrenal axis systems to aerobic physical activity (Baker, *et al.*, 2010). Specifically, a study by Baker and colleagues showed that a 6-month aerobic exercise program comprising four exercise sessions per week (45 to 60 minutes each) yielded significantly better improvement on executive function tasks for women, and this was associated with improvements in glucose disposal, insulin sensitivity, cortisol regulation, and plasma BDNF, which were all more improved for women compared to men (Baker, *et al.*, 2010). These findings suggest that women may show greater metabolic effects from exercise than men, which may contribute to its more prominent effects on cognition among females. Additionally, it is possible that exercise may have developmental effects on brain structure and function that differ between males and females. For instance, adolescent boys and girls differ in the magnitude of correlations between brain structure volumes and cognitive performance (Yurgelun-Todd, Killgore, & Young, 2002; Yurgelun-Todd, Killgore, & Cintron, 2003). Further research may need to explore how physical activity may play a role in these associations.

Most prior studies on the role of physical exercise in cognition have focused primarily on cognitive capacities such as executive functioning, attention, and processing speed, which are easily affected by state variables such as fatigue, mood, and sleep loss. Although fewer studies have focused on relatively stable cognitive capacities such as intelligence, evidence suggests that even these capacities are affected by physical exercise. One study of Grade 3 children found that a 30-min. physical activity period just three times a week during the school year was associated with improved academic achievement scores and higher scores on a measure of fluid intelligence (Reed, *et al.*, 2010). Similarly, a study of older patients with chronic obstructive pulmonary disease showed that engagement in a 3-month exercise program led to significant improvement on an index of fluid intelligence (Etnier & Berry, 2001). The present cross-sectional data are consistent with these prior findings, as greater levels of exercise were associated with higher measured full scale intelligence and performance IQ in women. The role of exercise on performance IQ suggests that these

motor and visuospatial capacities may be more amenable to the effects of physical activity than verbal abilities, or alternatively, that those with greater motor capacities are more likely to seek out physical activity.

The present findings should be considered in light of several methodological limitations. Because these data are cross-sectional and correlational in nature, it is not possible to infer the causal direction of the relationship between physical activity and intelligence. While considerable longitudinal evidence suggests that greater physical activity leads to positive improvement in cognitive functioning and brain health, alternative explanations for this association cannot be ruled out in the present study. For instance, it may be that individuals with greater intelligence are more likely to seek out physical exercise due to greater knowledge regarding the importance of exercise for general health. It is also well known that higher intellectual capacity is generally associated with greater financial income and upward mobility. Persons with greater financial resources are more likely to live in more affluent neighborhoods where it may be safer to exercise or where access to physical fitness facilities may be easier. The present data argue against these explanations, however, as the correlations between exercise and intelligence scores were just as high or higher after statistically removing the effects of socioeconomic, demographic, and cultural factors that might confound these relationships. Nonetheless, it is also possible that early socialization or income disparities between genders may contribute to the observed relationships in ways that were not controlled or evaluated. Future research would benefit from more specific control of these factors, as well as from the use of prospective longitudinal data collection in healthy adult samples. Additionally, only a limited set of self-report questions were asked regarding physical activity. Consequently, this analysis did not address the type of exercise (e.g., aerobic vs strength training) and the present data did not account for the duration of lifetime exercise or activity habits, each of which could also affect the data. With due consideration to the aforementioned limitations, the present findings suggest that there appear to be sex differences in the relation between physical activity and IQ. As described previously, some initial work suggests that such sex differences may be due to factors associated with the effects of exercise on glucoregulation and/or insulin sensitivity, but further research is needed to explore the potential mechanisms underlying these differences.

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USAMRMC Office of Research Protections
Human Research Protection Office
Continuing Review Submission Form

SUBJECT: "The Neurobiological Basis and Potential Modification of Emotional Intelligence Through Affective/Behavioral Training," Submitted by Dr. William D. Killgore, McLean Hospital, Belmont, MA, Proposal Number 08355002, Award Number W81XWH-09-1-0730, HRPO Log Number A-15731.

CONTINUING REVIEW SUBMISSION TO THE HRPO

This form is required to be submitted with current continuing review documents to the U.S. Army Medical Research and Materiel Command (USAMRMC), Office of Research Protections (ORP), Human Research Protection Office (HRPO). Please complete the following questions to determine the appropriate documents to submit to HRPO.

Please email the completed form, the IRB approval letter for continuation of the study, and any supporting documents that are necessary, as determined below, to the Continuing Review Mailbox at USAMRMCHRPO@amedd.army.mil.

Please note that the HRPO also conducts random audits at the time of continuing review and additional information and documents may be requested for review.

1) _x_ Local IRB continuing review approval letter with next expiration date. *(Required for all submissions).*

2) Please check whether any of the following study related events occurred during the continuing review period AND have not been reported to HRPO.

Y	N	
__	_x_	Major modifications to the research protocol and any modifications that could potentially increase risk to volunteers, during the continuing review period. (Major modifications include a change in Principal Investigator, change or addition of an institution, elimination or alteration of the consent process, change in age range or change in/addition to the study population or a change that could potentially increase risks to subjects).
__	_x_	Deviations to the subject protocol that affects the safety or rights of the subject and/or integrity of the study data.
__	_x_	Serious adverse events related to study participation, deaths related to study participation, or unanticipated problems involving risks to subjects or others.
__	_x_	Suspensions or terminations of the research by the IRB, institution, Sponsor, or regulatory agencies.
__	_x_	Subject complaints about the research.

3) If you checked 'No' to all items in question 2, submit a copy of the local IRB approval letter for the continuation of the study to HRPO. Skip to number 5.

4) If you checked 'Yes' to any of the items in question 2, submit the following additional documents and information to HRPO.

__ The continuing review report that was submitted to the local IRB.

__ Amendment submission forms and associated IRB approval letters for major amendments that occurred throughout the last review period and were not previously submitted to the HRPO.

If there were amendments to the protocol, Informed Consent Form (if applicable), or any other protocol related document that occurred during the last period and the amendments were minor, the date of IRB approval and a description of what changes were made should be summarized either in the Continuing Review Submission Form or in a separate memorandum.

__ Current copy of protocol.

__ Current informed consent form and HIPAA authorization (if appropriate).

__ A summary of HRPO reportable study related events that occurred throughout the review period. **Please see question 2 above for a list of events that are reportable to HRPO.**

The summary should include:

- Date of occurrence.
- Description of the event.
- Date that the event was reported to the IRB of record.
- Any related IRB dispositions of the event (if applicable).

5) Signature of Principal Investigator _____

6) Date (DDMMYYYY) 10/30/2012

7) Name of individual to contact with questions regarding this submission Sophie DelDonno

8) Contact phone number (617) 855-2281 **e-mail:** sdeldonno@mclean.harvard.edu